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UNDERSTANDING DEVELOPMENTS IN COMPUTER TECHNOLOGY: A PRAGMATIC AND SYNTHETIC INTERPRETATION

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ABSTRACT

Understanding Developments in Computer Technology: A Pragmatic and Synthetic Interpretation

This thesis constructs a new concept of technology which it uses to explain developments in computers and their practical application.

The need for this reconceptualisation is demonstrated by a survey illustrating the variability and contradictions between existing uses of the term 'technology', in particular their tendency to emphasise either its concrete or abstract attributes.

The possibility of using positivist principles as the basis for a comprehensive concept which can synthesis these two orientations is examined and rejected.

Instead, the new concept is constructed with ideas drawn from the work of various non-positivist theorists, principally Marx and Foucault. The result is not a definitive list of characteristics, but a description of the relationships in which technology is used and through which it changes.

In order to explore the potential of this concept, it is used to develop an understanding of various aspects of computer technology. Firstly, historical events which led to the construction of the first modern computers are described and their interpretation in terms of the synthetic concept of technology contrasted with ones derived from a positivist causal analysis.

In its second application to computer technology, the synthetic concept is used to interpret changes in contemporary methods of developing commercial data processing systems. This discussion is then reinforced and expanded through an interpretation of developments in current research into artifical intelligence.

Finally some broader social implications of the case being made by the thesis are examined. Limitations in its argument for this purpose are seen to arise both from the methodology adopted and the narrow empirical domain which has been considered. Consequently new directions of research which will further validate its conclusions are identified.

CONTENTS

CHAPTER 1

THE NEED FOR A NEW CONCEPT OF TECHNOLOGY

THE PROBLEM OF 'TECHNOLOGY'

'Technology', says Langdon Winner, 'is a word whose time has come' (1). What was once a subject discussed only by those directly involved, and then only in technical terms, has now become a topic of everyday conversation and social debate. We have been awakened, argues Winner, to a realisation that it is an integral part of society. And yet, he suggests:-

> Many of our standard conceptions of technology reveal a disorientation that borders on a dissociation from reality. (2)

This thesis will develop and demonstrate a concept of technology which explains that 'disorientation' and explores some of its implications. The significance of such a project cannot be underestimated in a society which increasingly explains both its ills and the possibility of their resolution in technological terms (3).

The research from which the thesis has emerged began as an enquiry into the social conditions in which technical knowledge develops. Its empirical focus was to be knowledge about the use of computers; in particular, it sought to explain how technology which was almost unknown forty years ago has become part of the everyday language and practices of commercial and industrial organisations. The research was to have been grounded in statistical evidence on factors such as the education and training received by those involved in developing and applying knowledge about computers. However, in undertaking this work two significant difficulties emerged. The first concerned the practical problems, for a part-time researcher, of collecting this type of information. In itself this difficulty may not have been insurmountable, but in considering possible solutions I was led to recognise that the very conditions which created these problems also represented a unique opportunity for a different form of research. This arose from my personal involvement in the work with which the study was to be concerned and gave rise to the possibility of looking at computer technology from the novel perspective of an expert participant. It seemed both practical and challenging, therefore, to redirect the emphasis of the research in order to explore the opportunities this methodology offered.

That decision was reinforced by the second difficulty arising from the original formulation of the research. This emerged from reading studies on management and organisations (4). The object of the reading was to devise a definition of technology which put into context the role of computers within commercial organisations. However it became clear that the term 'technology' was being used in many different ways; in some cases refering to machines, in others to methods and processes, and in others to knowledge about machines or methods and processes. Consequently, each use seemed to exclude some features of technology which were included in others. This reading, therefore, suggested a similar disorientation in formal uses of the term 'technology' to that identified by Winner in its common usage and it was clear that there were fundamental questions to be answered about the nature of technology itself before the proposed project could be undertaken.

This need for a clearer concept of technology led to further reading concentrating this time on studies in which 'technology' was being used in non-organisational contexts. Once again it was the differences, rather than the commonalities, which were most apparent. It was to be expected that the emphasis placed on technology in different studies would vary. Hence, in some cases it constituted a central focus in the author's argument, and in others, it was simply part of the implicit background to a discussion of another topic. Even so, the initial consequence of this additional reading was not a clearer concept of technology but even greater variation, not to say confusion. In trying to understand the relationship between the different uses, however, it emerged that they fell into two main categories. In the first, 'technology' constitued an independent variable with a specific relationship to the system of which it was a part. In the second category, it formed an integral and inseparable part of the system. Hence, in some uses technology assumed a concrete, objective and independent form, whilst in others it was an abstract and socially determined phenomenon.

It became the first task of the research, therefore, to clarify its use of the term 'technology' and the concept which underlay it. Of the uses already identified, none seemed adequate for this purpose, giving rise to the need for a conceptualisation which both resolved their contradictions and encompassed the various attributes which collectively they ascribed to technology. As a result, the project of this thesis has become an enquiry into the nature of technology itself and constitutes an attempt to construct an alternative and synthetic concept which hopefully overcomes the limitations of those in other literature. Computers have remained the empirical focus of this enquiry as a means of demonstrating the value of the new concept in understanding the processes by which technology is developed and changed. This demonstration is based on the method of expert participation made available by my own involvement in the everyday world of commercial systems development. The conclusions to which it leads are not entirely novel, but as a basis for understanding technology, in particular the development and use of computers, it provides additional evidence for what still remains the largely undeveloped view that the content of technology must be understood in terms of the social context of its construction (5). At the same time it provides an opportunity to evaluate the use of a methodology not typically used, or even available, to most forms of social research.

DEVELOPING A NEW CONCEPT

The thesis is divided into two main parts. The first reconstructs, in an idealised form, the search for a theoretically viable and fruitful conceptualisation of the term 'technology'. The second part then addresses some problems raised by the development of computer technology, so providing empirical support for the new concept of technology constructed as a consequence of this search.

The search begins, in chapter 2, with a survey of the ways in which 'technology' is used in formal literature. This demonstrates the range and variation of the different uses and, as a basis for classification, locates them on a spectrum, ranging from those uses which emphasise the concrete nature of technology, in the form of tools and machines, to those which focus on its ideational or ideological role. Along this spectrum other meanings are identified which emphasise these two extremes to varying degrees. Around the mid-point are uses for which the essence of technology is seen to reside in knowledge per se. Far from reconciling the alternative emphases, however, these examples simply reinforce the dichotomy by defining knowledge itself in concrete or abstract terms. Of the uses included in the survey, some are found to be too wide and imprecise, but most limit the scope they ascribe to technology by tailoring it to the case being argued.

The conclusion to be drawn, therefore, is that technology exhibits more attributes then any single use adequately allows for. More fundamentally, none is found which provides a basis for synthesizing the emphasis on concrete aspects of technology on the one hand and its abstract features on the other. However, the explanation for this persistent division is not seen to lie in the individual uses of the term, but in the conceptualisations from which they are derived. Hence, it is found that the concrete/abstract dichotomy operates not simply to diversify the uses of 'technology', but as a represention of the theoretical division between those which employ a concept grounded in positivism and those which draw on alternative theoretical principles.

The next stage in the search, therefore, is an examination of the possibilities offered by these two alternative conceptualisations for creating a basis on which to build a synthesis of their separate inclinations. It begins, in chapter 3, with a consideration of the principles of positivism. These, it is argued, underlie both the concrete emphasis in popular notions of technology and those most commonly used in the literature. It is shown that these principles embody limitations which do not allow for the broader view of technology required to encompass its abstract features. These same limitations are also shown to preclude the possibility that positivism can be broadened by integration with another concept of technology which will enable them jointly to provide the synthesis being sought. It is concluded, therefore, that positivist principles do not provide an adequate basis on which to develop a study of computer technology.

Consequently, in chapter 4, the search moves on to examine the principles underlying non-positivist approaches, beginning with the work of Marx (6). Although there is no specific definition of 'technology' in Marx's writing, this very omission is seen to provide the possibility of an alternative to the positivist approach. Such a conclusion emerges not so much from the substance of Marx's writing as from the method of analysis which he applies (7). Although interpretations of his method differ, what becomes clear from reading Marx is that the machines, industrial methods and knowledge, which are typically taken to constitute technology in positivist definitions, cannot be understood as an independent parameter in the economic equation. Rather they must be seen as part of a complex web of relationships and entities which together constitute a society. The resulting concept of technology is not encapsulated in a static definition but emerges from an understanding of its role in the social totality without which it has no existence.

This basic premise is developed by drawing on the work of a number of other theorists. These writers are not concerned primarily with technology, but the theoretical principles they develop are significant in this context. Their individual work is not described or discussed in depth; instead a selective presentation is used to generate ideas which contribute to the construction of a new understanding of the nature of technology. The outcome is not a definitive statement, but a description of the relationships within which technology originates and is changed. The resulting concept facilitates the incorporation of the various attributes of technology and relates them in a way which bridges the concrete/abstract dichotomy. A key relationship in achieving this synthesis is that between technology as a resource and its application in situated action. As a resource it consists of possibilities and constraints which are imprecisely stated and whose full scope cannot be expressed in this form. In action, part of this resource takes a more concrete and definite shape. As a result, it is placed within boundaries which limit its scope and exclude some of the potential within the resource from which it is drawn. This relationship between technology as a resource and technology in action, therefore, is essentially pragmatic. The resource provides the means to meet a particular requirement in action and, in turn, the consequences of that application act back on the resource either by reinforcing it or changing it, depending on its practical value in the given context (8).

By the end of this first part of the thesis, therefore, two main themes emerge. One theme concerns the fundamental limitations inherent in positivism which circumscribe its potential for developing an adequate concept of technology as a social phenomenon. The second theme concerns the practical value of the synthetic concept of technology which has been constructed as an alternative. This is demonstrated by the facility of the new concept for providing a better understanding, both of the way technology is applied and of how it develops. At the same time this second theme reinforces the first by demonstrating the limitations created by the positivist/mechanistic concept of technology and the restraints this imposes on the use and development of technology.

These two themes are developed in the second part of the thesis through an examination of computer technology. Chapter 5 begins by looking at the past with a discussion of some historical events which, in retrospect, are taken to be part of the historical origins of modern computers. Two interpretations of these events are offered which contrast a positivist, causal analysis with that suggested by the synthetic perspective. This illustrates the value of the latter's broad and pragmatic approach in which history is understood on its own terms and not through teleological reconstruction.

Chapter 6 considers some contemporary developments in commercial computing. It attempts to explain the nature of computer systems and the life-cycle of their development process and, in doing so, highlights the difficulties which are currently being experienced in controlling this process. It demonstrates, therefore, that the limitations of positivism, in the form of mechanistic models, not only exclude some possibilities for understanding technology but also constrain the way it is implemented in action. Even so, it is seen that positivist concepts are being applied both in explaining the difficulties of using computers and in prescribing appropriate remedies. In chapter 7, these issues are re-analysed in terms of the relationships described by the synthetic concept of technology. The difficulties are then seen to arise out of contradictions between the positivist/mechanistic principles being used and the nature of the reality with which they are dealing. Thus, it is argued, computer systems expose and are victims of the limitations and implications of the continued application of the positivist concept of technology. This case is reinforced by reference to artificial intelligence, a form of computer development which demonstrates, in particular, the danger of responding to contradictory experience by constraining the representation of reality to that which can be reproduced in a computer system.

In the final chapter, the case for a synthetic concept of technology is reassessed. It is argued that the understanding of computer technology provided by the empirical study confirms the utility of that perspective and, in consequence, also supports the critical analysis of positivism and its mechanistic derivative. Finally, this chapter considers some of the broader social implications of this discussion and identifies further directions for study which can strengthen the theoretical case and provide additional empirical support for it.

THE RESEARCH METHODOLOGY AND ITS EMPIRICAL FOCUS

Expert Participation

The form in which this thesis is presented has been constrained by the methods available for its construction. These, in turn, reflect the circumstances in which the research has been undertaken. The single most important circumstance has been that this work has coincided with my full-time career in commercial computing. As a consequence, the methodology which might have been expected in research of this type has not been adopted. Instead, I have used my special situation to provide a new perspective on, what is to me, the real and practical world of computing. The basic motivation for this research, therefore, may be seen as an attempt to make the everyday world in which I work understandable through the application of the sociological principles I encountered at university. The content of the thesis reflects this practical undercurrent both in its pragmatic approach to methodology and in its conceptualisation of technology. Thus when my initial project, based on 'normal' research concepts and methods, proved impractical, I was led to change its direction and to capitalise on the one resource undisputably available to me, my own participation, experience and expertise in the world of computer technology.

The principal method used in preparing this thesis, therefore, has been a form of participant observation, although one which seems to be largely ignored in discussions of that method in the literature (9). One of the clearest discussions of the issues arising from participant observation is that offered by Collins (10). Studies using this method, he suggests, are typically located on a continuum varying between 'complete observation', which minimises the intrusiveness of the observer, and 'complete participation', which maximises involvement in the events being reported. Collins, however, offers an alternative classification in which the poles of this continuum are represented as the embodiment of contrasting philosophical positions (11). Complete observation in his view represents the positivist approach to participant observation which aims to maximise the objectivity and replicability of fieldwork reports. By contrast, complete participation aims to provide an interpretive understanding arising from subjective involvement. Thus, he argues, the continuum is in reality not a continuum but a range of compromises which take the researcher further away from the philosophical ideals represented by the polar opposites which Collins labels 'unobtrusive observation' and 'participant comprehension'.

The case for a more directly participant analysis of science is made by Woolgar (12). Although he is concerned with detailed empirical investigations of laboratory science, his emphasis on science as it happens rather than as it is reported, for example in interviews with participants after the event, reflects something of the emphasis of my own method. Through its deep participation in the culture which it seeks to understand therefore, the method adopted in this thesis may appear to be an implementation of Woolgar's idea and to approach the ideal of participant comprehension. However, as Pinch recognises (13), even the sociologist who is technically competent in the area of scientific research under investigation achieves, at best, a limited member status in the participants' culture. Consequently there is a crucial distinction between the methodologies discussed by Collins and Woolgar and that used in this thesis, which I have labelled 'expert participation' (14).

The essential difference lies in the initial motivation and principal interests of the researcher. The expert participant is primarily involved in events as a participant and observation (the role of sociologist) is secondary to this concern (15). The researcher seeking participant comprehension, however successfully (s)he becomes part of the events being observed, is primarily motivated to participate for the purposes of interpretation. The distinction being made is similar to that which emerges in the discussion of expert systems in chapter 7. In that discussion it is argued that whilst there is a quantitive relationship between degrees of competence (measured for example by the accumulation of knowledge and experience in applying it), the difference between a highly competent performer and an expert is QUALITATIVE. Competence in the end always maintains a dichotomy between the actor and the object of action whilst the expert is part of the act itself. The expert does not perform in a situation but is part of it. In the same way, the reseacher seeking participant comprehension, however competent (s)he becomes in the field being studied, can never be totally identified with the events being observed. The expert does attain this level of participation and cannot therefore be located on Collins' range of compromises between participant comprehension and unobtrusive observation.

The principal difference in practice, therefore, between the form of participation employed in this research and that more usually encountered has been the closeness of my involvement with the subject being studied. This has left me uniquely placed to analyse the changes occurring in computer technology and to take advantage of the methods of sociological analysis to illuminate them. It has made me an insider in the world of computers rather than an intruder who had first to become accepted and familiar with the technicalities and jargon of the field of study. Similarly, it has avoided the possibility of a 'Hawthorne Effect' (16) whereby my presence as researcher inhibited or motivated those I was observing. There are, of course, dangers in this familiarity. In particular, I have had to be aware of the danger of accepting the assumptions which are a necessary part of everyday life in this environment. These dangers were lessened because I had worked with computers for seven years before taking my first degree so that the contrast between the assumptions used in that work, and the questions raised by sociological analysis, were brought sharply into focus whilst I was studying for my degree rather than afterwards. The subsequent research, therefore, has been a process of refining and developing the fruits of this meeting of contrasting epistemologies.

Even so there has been a sense of living a dual existence. Practical considerations mean that in my day-to-day work I employ the assumptions and legitimations appropriate to it; indeed I have been better able to do so because they have been made explicit. The very clarification of the principles underlying the techniques used in computing has enabled me to apply those techniques more effectively. Only outside the workplace am I free to employ the alternative perspective developed in this thesis; to do so at work in anything but a superficial way would make me an outsider (17). Once the pragmatic nature of this duality was clarified in my own mind, there has been neither difficulty nor conflict in moving between these two roles nor in allowing each to inform the other. It is, after all, a common experience for people to take on a number of social roles (such as father, employee, team member), although less common for them to consciously differentiate them. Thus, in the words of Sumner:-

> What research must bear in mind always is that an observation is partly determined by the appearances observed, partly by the observing ideologies and partly by the social relations under which the observation took place. (18)

All observation is a situated practice, but the duty of the 'scientific' observer is to recognise the nature of this practice and the assumptions being employed. This I believe I have done. Only a critical consideration of the results of this research by others can determine whether I have been deluded in this confidence.

In addition to these 'ethical' considerations, the method used has presented a number of practical advantages and disadvantages, many of which revolve around what for the part-time researcher is the key factor, time. Time to do the work is inevitably an important consideration and in my own case this has varied with the competing demands of my full-time employment. The consequence has been long periods in which no work could be done on the thesis and an overhead in refamiliarising myself with each section as I took it up again. More significantly, however, the total period which has elapsed between beginning this work and concluding it has been considerably longer than would normally be expected for such a project and in that time there have been considerable changes in both the theoretical and the empirical domains which the thesis explores. In terms of its theoretical development, the main consequence has been an increasing isolation from the academic mainstream in which the issues raised by this work have been exercised (17). Even so, this has been less significant for the final result than the consequences for the empirical work.

The main feature in this context has been the rapid pace of change in computer technology and the constant stream of literature which has emerged to support it. There have been significant developments in all aspects of the subject including the equipment available, the types of system being developed, and the methods employed to develop them. This has created an almost irresistible temptation to continually take account of these changes, both in order to explain their occurrence and to use them as additional support for the case being argued. Developments in the methods of designing and building computer systems, for example, have meant that, whilst the original target of this investigation was a relatively crude form of mechanistic thinking, it is now considerably more sophisticated. At the same time, the increasing evidence of contradiction and difficulty in applying mechanistic concepts in computing has led others to the type of questioning which first instigated my own work and thus detracted somewhat from its novelty. It can be seen, therefore, that the consequences of the protracted time-scale of this work have been mixed. On balance, I believe that the added empirical support for its arguments, and the development of my own experience in the new methods being used, provide advantages which outweigh any disadvantages which have been encountered (20).

Clearly, therefore, expert participation involves compromises both for the 'participant' in order to be able to comment on the field of study and for the 'sociologist' for whom there are the dangers of over-familiarity. Although these can be identified at an intellectual level, the implications of adopting this method and the resulting compromises are best revealed through their application in this thesis. The conceptualisation of technology which it develops is a realisation of the principles underlying the method which therefore becomes woven into the fabric of the argument. As a result it would do no justice to the method to identify parts of the thesis which derive primarily from participation and others which result from academic reflection. On the contrary, the thesis is a consequence of the constant and undifferentiated interaction between these two states.

Computers as an Empirical Focus

If I were to rationalise the original decision to undertake research, I would probably talk about an interest in relating the things I had done at university to the work I do now. The original choice of empirical subject may, therefore, have been fortuitous. Once I decided to engage in research, however, there were clear practical advantages in basing it on an area of social activity in which I was immediately involved. However, when a need to reconceptualise technology became the prime concern of the work, it was not clear exactly how this would relate to an empirical study of computer technology, or rather, what applying a new concept of technology to computers would reveal. In practice, computer technology has proved a particularly fruitful choice of subject with two important advantages for demonstrating the new concept.

The first advantage arises from the speed of change which computer technology has experienced over the past forty years. In this relatively short time, in historical terms, computers have moved from scientific obscurity to being a pervasive feature of industrial societies. This compression of the historical process of technological development (21) provides especially good material for demonstrating the synthetic concept for which change is a cornerstone of its potential for explaining how technology has developed. The opportunities provided by the speed of change have not been the only benefit of computers as an empirical subject. Even more important perhaps, is the nature of computer technology itself which differs from other forms of technology in two significant ways. Firstly, it does not provide a physical force but a logical one, a technology for the mind rather than the body. Thus the principal applications of computers do not replace or supplement human physical capabilities but are concerned with the products of their mental capacity. They do not, for example, lift heavier weights or increase the speed of a production-line (22), but they do process data untiringly and at great speed.

As a result, another important difference between computers and other forms of technology is that computers reverse the tendency to specialisation found in traditional technology. Rather than limiting their functions to those required by a particular process, they succeed by adaptability and flexibility. The consequence of this difference is that they do not fit easily into existing models of technology which are based largely on physical and mechanistic concepts. Any attempt to understand the nature of computer technology, therefore, necessarily shows up the limitations and weaknesses of these models which never the less continue to dominate everyday orientations to the world including those employed in computer technology. It is the resulting contradictions experienced in developing computer systems which can explain the disorientation identified by Winner and which, through its empirical focus on computers, this thesis is able to demonstrate and explain.

Some Consequences of the Methodology and its Subject

The consequences for the thesis of its particular mode of research and its subject matter are demonstrated in the final form it takes, in particular, in the balance between its theoretical and empirical elements. It will be seen, for example, that much of the theoretical debate is based on literature available at the end of the 1970's, although the more recent interest in Foucault has added an important dimension to that aspect of the thesis. By contrast, much of the empirical evidence is very recent and drawn, not from academic literature, but from professional journals and promotional material. The role of the theoretical work in this arrangement is to extract ideas and concepts in order to generate a working hypothesis on which an empirical investigation can be undertaken. The latter, by maximising the advantages of my particular method of research, has sought to confirm the practical value of that hypothesis and provide a basis for its further application and development.

Perhaps the most obvious evidence of the pragmatism of this approach is the way existing literature has been used. This is typified by the survey of uses of 'technology' which sought to establish the need for a new conceptualisation of technology. The examples used in the survey were those originally identified in the context of organisational and managerial studies supplemented by further reading undertaken in the search for clarification of the concept of technology. For this purpose it was assumed that the use of 'technology', or a similar term, was sufficient to warrant inclusion. It was not the object of this survey to provide a complete reference guide to the different uses of technology, but to:-

a) demonstrate the limited nature of most usages, definitions and concepts of 'technology', and

b) identify a possible basis for a more adequate concept.

The survey does not claim to be comprehensive, therefore, nor does it undertake a detailed description or critique of the various works to which it refers (23). None-the-less, it has proved sufficient for the first of these purposes in that it demonstrates the variety of uses and some of the limitations that this variety has created. The resultant classification based on an emerging pattern of usage, suggests that these examples are also sufficent to demonstrate the different facets of technology which have to be accounted for by the synthesising concept. The basis of categorisation, therefore, is very simple. If its principal purpose had been a detailed analysis of the uses of 'technology', it could have adopted a more sophisticated basis for this purpose (24). For the objectives outlined above, however, this single dimension is sufficient to demonstrate the dichotomy between uses of 'technology' grounded in positivist principles and those which are not. It is on these two alternatives that the search for a suitable basis for a new concept has been concentrated.

In using texts in this way, the researcher always leaves open the possibility of criticism based on other texts or alternative interpretations. However writers, like speakers, have an audience and a purpose in communicating. Their work is constructed to convey a message and must employ usages and meanings understood by that audience either by explicit definition or the indexical interpretation of shared concepts. Only where a work is seeking to deviate from common usage is it likely to discuss fundamental meanings, and even then they must be expressed in terms and categories familiar to the audience. On this basis, it has been assumed that in finding a sufficient number of terms and ideas which are in common use, the survey of uses identifies the range of possibilities available and the theoretical assumptions which will typically underlie similar texts.

Similar considerations apply to the use of texts in constructing the synthetic concept. Here the writers discussed are more concerned with theory and less with the practical issues which exercised most of those included in the survey of uses. Consequently they are more likely to examine the concepts being used. Once again, however, the purpose is not to enter into a detailed debate on the theoretical validity of their positions, but to range selectively through them, identifying their underlying direction and concerns and extracting ideas and concepts for my own use. This approach may be considered less ambitious than the alternative, but it reflects the pragmatism pervading this thesis. It is based on the assumption that any text may be considered not only as a statement by the writer, but as a resource which the reader can approach with a personal project. Thus any completed text becomes part of the public domain where its interpretation is indexical to the context in which it is used. Just as new ways may be found to use existing technology, so texts may be employed in ways not intended by their originators.

The final justification for the treatment of other texts in this thesis must be its success in employing them as a resource to stimulate and develop a new concept of technology. Consequently the use made of them should judged within the totality of the argument presented by this thesis, and not in terms of their original context, from which they has been extracted. The critical concern should not be the interpretation of the original works, but the adequacy of the concept of technology which they have been used to construct.

It will be clear from this description of the thesis and its methodology that both owe a great deal to the circumstances in which the research has been undertaken. The original motivation, the subject matter and the methodology are all a direct consequence of my position as a part-time researcher and full-time computer professional. The need for a new concept of technology and the possibility of demonstrating it derive from the, originally, fortuitous choice of computers as an empirical focus. The balance between theory and empirical demonstration, and the pragmatism which this typifies, reflect the underlying practical concern of the research with my daily working environment. The limitations of its conclusions and the potential for further development are also a result of its particular format. I believe that these circumstances have created an opportunity for a novel form of research and an unusual, but viable, perspective. The final judgement of their merit, in keeping with their pragmatic origins, must be based on how useful they prove to be as a resource for others in developing their own understanding of technology.

NOTES FOR CHAPTER 1

1. Winner L. 'Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought', 1977, MIT Press, Cambridge Mass., p. 4

2. Ibid. p. 8

3. In discussing a report on NATO's propored use of nuclear weapons, the *Sunday Times* (5/2/85) quoted Sir Frank Cooper, one of its authors, as saying that:-

   > Technology is a two-edged sword, and if it goes unchecked the whole of space will become a battle-ground by the end of the century. We want to see that stopped. On the other hand, in the event of a war in Europe, it does offer us the chance of buying more time and thus lessening the chance of a nuclear exchange.

   The conclusion of the report was that NATO should reject plans for a 'controlled step-by-step escalation' using large and vunerable weapons platforms like ships and tanks, and concentrate on small but highly accurate missiles which could reduce the advantage of numbers held by the Warsaw Pact countries. The argument therefore is concerned entirely with the appropriate technology to use and assumes that the solution must be stated in those terms.

4. e.g. Woodward J. 'Industrial Organisation: Theory and Practice', 1965, Oxford University Press, London: Blauner R. 'Alienation and Freedom: The Factory Worker and his Industry', 1964, University of Chicago Press, Chicago

5. see for example Pinch T.J. and Bijker W.E. 'The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology might Benefit Each Other', in *Social Studies of Science*, Vol. 14 No.3, Aug. 1984

6. This use of the term non-positivist is not meant to imply a homogeneity in the various positions which do not adopt positivist principles.

7. A number of commentators have emphasised the importance of Marx's method for understanding his work, e.g. Cleaver H.M. 'Reading "Capital" Politically', 1979, Harvester Press, London: Godelier M. 'Structure and Contradiction in "Capital"' in Blackburn R. (Ed.) 'Ideology in Social Science', 1972, Collins, London: Althusser L. 'For Marx', 1977, New Left Books, London

8. This pragmatic resource/action relationship applies equally to the concept of technology itself, i.e. the concept is a resource to be used in understanding technology.

9. see e.g. Spradley J.P. 'Participant Observation', 1980, Holt, Rinehart & Winston, New York.

10. Collins H.M. 'Spoonbending:Concepts and Practice of Particapatory Fieldwork' in C. Bell & H. Roberts (Eds) 'Social Researching: Problems, Politics and Practice', 1984, Routledge & Kegan Paul, London

11. A similar argument is developed in chapter 2 of this thesis with regard to uses of the term 'technology'.

12. Woolgar S. 'Laboratory Studies: A Comment on the State of the Art' in *Social Studies of Science*, Vol. 12 No.4, Aug. 1982)

13. Pinch T.J. 'Confronting Nature', 1986, D Reidel, Dordrecht

14. The term 'expert observation' could perhaps have been used with equal justification. It is the element 'expert' which is significant for the present purposes.

15. This role is not the same as that of 'engineer sociologist' (see Bijker W.E, et al (Eds.) 'The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology', 1987, MIT Press, Cambridge Mass.) where the engineer necessarily, but unconsciously, undertakes a sociological analysis of the environment in which a technological artefact will be used. The expert participant deliberately engages in analysis of the events in which (s)he participates directly.)

16. see Pugh D.S. et al 'Writers on Organisations', 1971, Penguin, Harmondsworth, pp. 127-8

17. It would also possibly make me unemployed.

18. Sumner C. 'Reading Ideologies', 1979, Academic Press, London, p. 226

19. An indication of more recent work in the sociologies of science and technology is given in the brief review of the literature in Pinch T.J. and Bijker W.E. 1984 op cit.

20. It is perhaps ironic that one of the practical advantages of these developments has been the availability of home micros for word processing without which it may not have proved practical to complete this thesis.

21. see Mumford E. & Ward T.B. 'Computers: Planning for People', 1968, BT Batsford Ltd., London for the comparative rates of development for motor cars, aircraft and computers.

22. Computers may, of course, be indirectly responsible for such physical forces, for example by controlling robot machines.

23. Indeed the use of 'technology' is so pervasive that any comprehensive survey would be impossible.

24. see e.g. Burrell G. & Morgan G. 'Sociological Paradigms and Organisational Analysis', 1979, Heinemann, London. They use two dimensions, one defined by the subjective/objective debate in sociology and the other by what they call the sociologies of regulation and radical change.

CHAPTER 2

MEANINGS OF TECHNOLOGY

THE MULTIPLICITY OF MEANINGS

In its original, seventeenth century usage, 'technology' was a generic term for the 'industrial arts' referring to the skills used in production and management. In the eighteenth and nineteenth centuries, where the term was used at all, it had a more concrete and precise meaning usually rendered as machines, factories or engineering. Since then, in Winner's words:-

> In a dialectic of concepts that Hegel would have appreciated, the word has come to mean everything and anything; it therefore threatens to mean nothing. (1)

Such ambiguity and variation can be expected in the conversational use of a term which refers to a pervasive feature of society, but in the case of technology, there is an equally bewildering diversity of meanings employed by those who have used the term more formally. This chapter presents a representative survey of these latter uses to demonstrate their variety and contradictions (2). It does not offer a detailed examination or criticism of each one, nor of the discussions in which they are used, rather it illustrates the range of attributes which collectively they ascribe to technology. In the process it identifies a dichotomy between those uses which emphasise the concrete features of technology and those concerned with its abstract nature. It also shows that many of the meanings ascribed to technology have been constructed to support a particular argument without establishing a full understanding of its different aspects. This survey will demonstrate, therefore, why the construction and demonstration of a new concept of technology has now become the principal objective of this thesis, when in its original project the definition of technology was simply to be an introduction to the main discussion.

In order to present this survey, it was necessary to provide some basis for classifying the different uses of technology. However, the variety of these uses is reflected in the number of ways they have been classified. Aron, for example, identifies two general classes, the first being concerned with 'the tools and products of industrialisation' and the second with 'any rationalization of an activity with a view to manipulation or planning ......' (3). Hence one reflects the concrete implementation of technology and the other its abstract form.

Rapp on the other hand suggests four categories (4):-

a) the 'engineering' perspective which equates technology with machines,
b) a philosophy of culture approach which sees it primarily as a way of thinking,
c) a critical approach typified by the Frankfurt School,
d) the systems theory approach which emphasises the balance of nature.

His first two categories may be equated with Aron's whilst the others recognise differing socio-political views of technology. As Rapp comments:-

> This overview, which is by no means exhaustive, already shows the many ways in which technology can be interpreted and evaluated. (5)

Gendron (6) provides a third classification which he bases on different evalutions of the social impact of technology. His first category, the utopian view, sees technology as a progressive and liberating force. The second, dystopian, view portrays it as a dangerous and disruptive element, at least in modern industrial societies. The final category, which Gendron identifies as socialist, argues that in itself technology is neither beneficial nor harmful and it is only through its application that it takes on these characteristics. Each of these views implies a different form of political action. Utopians argue that any potential dangers of technology can be contained by making suitable adjustments to existing social and political institutions. Dystopians, however, argue that technology and society are so intimately related that the harmful use of technology can only be ended by a radical change in the society which determines how it is used. The socialists adopt a middle course, agreeing that technology may prove harmful in its present use, but maintaining a distinction between technology and society so that their solution is to change society in a way which will lead it to use the existing technology in a more satisfactory way.

The various meanings given to technology and their classifications both tend to reflect the interests of the writers using them and the argument they are presenting. This thesis is no different. It identifies and classifies uses of 'technology' in pursuit of its own objective of a comprehensive understanding of the phenomenon. Initially, it does not locate these different uses in discrete categories but on a continuum whose poles represent concrete and abstract extremes of emphasis. Ultimately, however, it recognises that no single use adequately spans both these aspects and identifies them as two distinct classes of meaning.

The concrete, essentially positivist, class is characterised by a concern with the instrumentality of technology and treats it as an independent variable in a social equation. Typically it focuses on specific areas of application rather than on technology as a whole, supporting the idea of multiple technologies each defining an area of specialisation and expertise. There is a close relationship between technology and science which encourages the view that technology is independent, neutral and objective. Any harmful outcomes are portrayed as the responsibility of those using the technology rather than a feature of the technology itself.

The abstract class of meaning emphasises the totality of technology and characterises it as a mode of reasoning and orientation to the world. Its instrumentality is not denied but is not seen as a significant feature. Technology is treated as an integral part of a society and is typically described in terms of its own domination of social processes or as a tool of a dominant class or group. Questions are directed, and criticisms levelled, not at specific instruments and techniques but at the general processes which construct and reproduce them.

CONCRETE VIEWS - TECHNOLOGY AS THINGS

Organisational Analysis

Typical of the concrete view of 'technology' is its use by writers on management and organisation for whom it represents an analytically separate variable in a causal relationship. Sayles (7), for example, examines the inter-relatedness of formal and informal structures in organisations and distinguishes four types of workgroup based on the levels of skill and interpersonal interaction they involve. His interest is not so much in the formal structures within these groups as with their relationship to the technological and organisational setting in which they exist. In defining these relationships, Sayles identifies technology as the determining factor. According to Silverman however:-

> It is difficult to see how this analysis, based on workers drawn only from 'mass production' industries, can be given any general validity. (8)

Blauner (9), on the contrary, specifically examines industries based on different types of technology. His basic thesis is that technology itself, rather than any specific implementation of it, is an alienating factor in modern industry. The degree of alienation varies according to the technological basis of the work being done so that craft work is the least alienating and assembly-line work the most alienating. Like Sayles, therefore, Blauner sees technology as the determining factor and argues that the social organisation of the factory is a consequence of the technology in use.

Woodward (10) also studies different industries. Her interest is in formal organisation which she also sees as being determined by the technology in use. She categorises industries in terms of the complexity of their technology with small-batch production as the least complex and process control industries as the most complex. She identifies the structural features typical of each category and concludes that there is a common organisational form appropriate to industries with a similar level of complexity. Those which contradict this rule will tend to be less successful than others which conform to it.

In spite of its use as a determining factor in these various studies, this view of technology has a number of practical difficulties. According to Perrow:-

> The foremost has been the measurement (and thus the definition) of technology itself. To be pure, and to keep the concept independent of structure, we should focus upon characteristics that are measured independently of human behaviour ...... (11)

According to Gallie, attempts to do this have been noticeably unsuccessful:-

> ...... within a perspective which regards technology as a crucial variable there is no conceivable way of accounting for the very striking differences in worker attitudes uncovered by the different studies. (12)

Despite this criticism, such studies, with their quasi-scientific approach, have proved popular with managers. Rose believes this is because both the managers and the studies, in spite of the latter's apparent objectivity, are part of the history of capitalism and share in its assumptions and objectives (13).

An attempt to overcome the problems of using technology as an independent variable is to be found in Pfeffer's 'Organisational Design' (14). He reviews the literature on technology and organisation and concludes that it has converged to the point where the major role of technology is seen to be its influence on the forms of control within an organisation (15). He proposes to develop this argument further in order to free technology entirely from a causal framework. As an alternative to the reified model of organisations necessitated by that framework, he adopts an 'action frame of reference'. This focuses on the personal projects and resources of individuals within the organisation rather than treating the whole organisation as a single entity to which interests and goals may be attributed. Technology then becomes one resource available to the members of an organisation and is determined by them rather than being a determining factor. As a result it becomes a much more amorphous feature of the organisation.

> Whether we define technology as what occurs in the transformation process, as the connections between actions and consequences, or as the methods and mechanisms for accomplishing organisational tasks, it is clear that technology is more than the organisation's machinery. Indeed, a close examination of these definitions may reveal that technology is the organisation's activities. Anything that goes on in an organisation can, at some level, be related to the organisation's work and tasks, and therefore, can be considered part of the organisation's technology. (16)

Thus Pfeffer only overcomes the difficulties inherent in defining technology as an independent variable by allowing it to be totally absorbed into the concept of organisation. As a consequence, his argument becomes indistinguishable from a general theory of action (17).

<u>Technology as Objects</u>

While organisational studies have tended to define technology in terms of industrial production, other studies are primarily concerned with the objects which are being produced. Price, for example, defines technology as:-

> ...... that research where the main product is not a [scientific] paper, but instead a machine, a drug, a product, or a process of some sort. (18)

Price is stressing the concrete nature of technology to support his argument that it does not simply represent the practical application of science but has a distinct development path of its own with a different type of result. Hence, whilst the principal outcome of scientific research is its published results, technological research creates new products. Science and technology, therefore, each derives new knowledge from that already available within its own domain, and follow distinct, if inter-related, paths of development.

Lawless also includes the output of research in his definition of technology:-

> For the purposes of the study, 'technology' was broadly defined to include all varieties of applied physical and biological science and engineering, and also basic research that might soon lead to a proposed technological development. (19)

He uses this definition to discuss a number of cases in the

United States where an uncritical acceptance of technology has been shaken by the revelation of dangers inherent in its use. His examples of such 'technological shock' include drugs, chemicals and industrial pollution. This concentration on concrete instances of technology is not unusual in attempts to create general awareness in a non-technical audience. It focuses attention and provides an object for action. By contrast, an abstract concept of technology is an elusive object for both protesters and critics. Those who take that path, as we shall see later in this chapter, are usually left with no basis on which to take action. Thus most anti-technological criticism is directed against specific targets such as an airport or nuclear installation (20). Lawless acknowledges that his own definition is geared to his particular argument. As a result, however, it focuses on easily identifiable, 'shocking' events and does not entail any discussion of other consequences of technology such as structural unemployment or long-term environmental pollution which are less concentrated and immediate.

THE MIDDLE GROUND - TECHNOLOGY AS KNOWLEDGE

The 'Socialist' View

Like Lawless, Ackroyd et al (21) also highlight specific implementations of technology to present their argument. They define technology as:-

> ...... any device or method which exploits knowledge from any of the sciences from physics to psychology. (22)

The particular implementations of technology which interest them are those used by the security forces in Ulster and range from CS gas and rubber bullets to methods of information analysis and interrogation. Their aim is:-

> ...... to show that the development of this more novel technology - the technology of political control - is the result of powerful social and political processes, and is itself part of these processes ...... Developments occur when they serve the purposes of those who control the resources which can put the technology to use, rather than when the basic scientific knowledge becomes available. (23)

Hence, they argue, technology develops not as the result of autonomous change or new scientific research, but when it suits the purposes of those who have the power and resources to implement it. In its role in political repression, therefore, technology is part of an equation which includes factors such as legislation and public opinion and which aims to maximise control whilst minimising resistance and the danger of a backlash. The essence of their argument is that the dominant groups in British society want to retain and increase their political control. Events in Northern Ireland have given them the opportunity to introduce anti-terrorist legislation and test new technology for this purpose in a way which has the support of the majority of the population.

The meaning given to technology by Ackroyd et al contains features which place it closer to the centre of the concrete/abstract continuum than those prviously discussed. Firstly technology is associated with broader moral issues characterised by its good and harmful effects. Furthermore this moral element is not simply added to an otherwise neutral technology when it is implemented, but is a consequence of the social structure within which the technology is created, and is built into it and shapes its form. A second feature is that the meaning of technology has been broadened to include methods and knowledge although these still take concrete form, for example in the use of psychology to develop interrogation techniques. The third feature is that technology is no longer seen as an independent variable but is discussed in relation to other social forces. It has become one aspect in a social equation which cannot be altered at will and which is not independently determined. Rather it must be balanced, for example by public acceptability. The argument as it is stated clearly implies that in a different society, not only would this technology of political control not be used in this way but that it could never have been created.

However it is not clear how relevant this argument is to technology as a whole and to what extent the authors would apply it to other concrete forms of technology such as industrial processes. A radical change in a society's basis of economic production is of a different order from changing the form of political control. The industrial basis of Germany was not changed in 1945 even though its previous political organisation was replaced by two alternative forms in the post-war partition. Similarly it is not clear to what extent the knowledge from which technology is developed is itself a specific outcome of the political structure of society. The implication is that it would be fundamentally unchanged in a society with a different form of political control.

The argument offered by Ackroyd et al would seem, therefore, to be a version of what Gendron describes as the 'socialist' view of technology. In this view the knowledge from which technology is derived is considered neutral and only to acquire moral values through its use to create technology, that is in the direct application of knowledge. Gendron's objective in examining technology is to identify the extent of its impact on society and in particular how far it is a force for good or harm. As we saw above, he identified three basic views of technology. The 'utopian' and 'dystopian' views represent technology as intrinsically good and harmful respectively, at least as it is found in modern industrial societies. Both are rejected by Gendron in favour of the 'socialist' view which he bases on his reading of Marx which he summarises as follows:-

...... all major economic transformations and hence all major social transformations are the result of the dialectical interaction of productive forces (technology) and production relations ...... Growth in technology (growth in the productive forces) is determined by production relations; production relations are in turn transformed by growth in technology. (24)

So, like Ackroyd et al, Gendron identifies a link between a society and the form its technology takes. Similarly he defines technology in terms of both knowledge and objects although his focus is on economic production rather than forms of political control.

A technology is any sytematized practical knowledge, based on experimentation and/or scientific theory, which enhances the capacity of society to produce goods and services, and which is embodied in productive skills, organisation, or machinery. (25)

Thus, although Gendron's definition demonstrates a move away from the concrete pole by including skill and organisation as well as machinery in its definition, it remains firmly grounded in the concreteness of positivism and the scientific method derived from it.

The same may be said of the work of D & R Elliott even though they stress the significance of social environment even more emphatically.

It is not the existence of 'technology' itself that is the problem, but rather the precise forms of contemporary technology. As such the question of 'technology' is inseparable from questions of social, economic and political structure ...... technology is not an independent variable; it is part of the network or system of

> interdependent parts that we call 'society'. (26)

Hence the choice of technology becomes one between systems of values which define its use.

> It is inevitable then that all aspects of technology - machines, buildings, transport systems and communications systems - reflect the particular beliefs as to the type of social and psychological relations that should exist between men and between men and the environment they live in. (27)

Thus they argue that:-

> ...... our whole social and economic, cultural and political system is permeated by technology. It is not just a matter of hardware and physical systems. (28)

They are not as forceful as Ackroyd et al in seeing dominant groups as determining the form of technology, although they recognise its role in reinforcing the dominance of existing groups within society. Even so, they argue, the interaction between technology and society allows variations in the directions which technology may be developed which in its turn implies the possibility of 'very different social, economic and political structures.' (29). The current structure of industrial societies, they suggest, encourages acceptance of the mediation of experts in determining the direction to be taken and hence the values embodied in our society. Their answer to this domination is an alteration in the franchise on the assumption that exposure to alternatives will lead the electorate to adopt different values and hence different uses of technology.

The Tendency to Confusion

The work of Ackroyd et al, Gendron and the Elliotts illustrates that definitions of technology near the centre of the concrete/abstract continuum typically emphasise the knowledge used to create technological objects. However this can create its own difficulties. A tendency to confuse technology as instruments and technology as knowledge is seen by Fores (30) as the most common reason for its variable use by economists. Freeman makes the same point arguing that:-

> [Technology] is one of the expressions which suffers from immense confusion in its use. Sometimes it is used exclusively in the original meaning of the word; a body of knowledge about techniques. At other times it is used to describe the actual physical hardware used for production. (31)

Bell illustrates this dual use of the term in 'The Coming of Post-Industrial Society' (32). Societies, he argues, consist of three elements, social structure, polity and culture. These represent three axial principles along which societies can develop; the allocation of resources, the form of participation and the nature of self-fulfillment. He recognises no necessary correlation between developments occuring in these three spheres; they may overlap, but they may also contradict each other. Societies, therefore, can be studied from a number of distinct viewpoints and for his own work Bell chooses social structure in the form of economic production. This focus, he believes, will avoid distinguishing between the United States and the Soviet Union which would not be the case in a study of polity or culture but which is necessary in view of his concern with the transformation from industrial to post-industrial economies which he believes both societies will experience. The key to this transformation is a change in the role of knowledge where knowledge is defined as:-

> ......*a set of organised statements of facts or ideas, presenting a reasoned judgement or an experimental result, which is transmitted to others through some communication medium in some systematic form* ...... Knowledge is that which is objectively known, an *intellectual property* ...... (33 - author's emphasis)

Although technology is another key concept in his argument, it is not explicitly defined. The reader is left therefore to determine the meaning given to it from the various indications provided. One such indication is in Bell's comment that:-

> The terms pre-industrial, industrial, and post-industrial societies are conceptual sequences along the axis of production and the kinds of knowledge that are used ...... Along the axis of production and technology, both the Soviet Union and the United States are industrial societies and thus somewhat congruent. (34)

So it would seem that we can equate 'technology' with the 'kinds of knowledge that are used' in production and that Bell is describing a concrete conception of technology in which its essence is knowledge. Such knowledge, once created, can become the property of experts and professionals.

However, at another point in his discussion, Bell treats technology and knowledge as separate categories:-

> We have said that technology is one axis of the post-industrial society; the other axis is knowledge as a fundamental resource. (35)

The explanation for these differences is that Bell uses 'technology' to represent two entirely separate concepts which are distinguished by their relevance to the historically distinct industrial and post-industrial phases of social development. Bell uses a change in the character of knowledge from practical to theoretical to distiguish between these phases but the consequencess of this change for the meaning of technology are implicit in his discussion rather than clearly defined. In the case of industrial societies, Bell is arguing, the main axis along which development occurs is production and knowledge about it. This leads him to a concrete perspective on technology which is seen to develop through experience and the piecemeal innovation of new machines and methods of production. Post-industrial societies are characterised by a new relationship.

> The concept "post-industrial society" emphasises the centrality of theoretical knowledge as the axis around which new technology, economic growth and the stratification of society will be organised ...... (36)

Science and technology combine in a new way to produce 'the systematic development of research and the creation of new science-based industries' (37). Technology is no longer typified by machines but by the application of theoretical knowledge in the form of general principles. It does not simply represent ways of doing things but a way of looking at them, an epistemolgy. So when Bell talks of 'knowledge' he means 'science' and the distinction he is making is between the 'unscientific' development of technology (industrial) and its development in a 'scientific' way (post-industrial). Thus, in post-industrial societies the key institutions are concerned with teaching and research, and the basis of stratification is skill.

Bell's dual use of 'technology' reflects his willingness to fragment his view of societies, both historically and structurally. His creation of strict categories however makes it difficult to give a meaningful explanation of the transition which has occured. Rather he is obliged to treat this as a pre-ordained path of development which all industrial societies will experience. Similarly, he can only explain the development of the non-economic aspects of society in terms of their own internal dynamics and not by relating them directly to changes in economic production. Thus he offers no basis for discussing the implications of technology, as an epistemolgy, for the cultural or political spheres of society, nor for bridging the concrete/abstract schism in the meanings of technology.

Knowledge and the Development of Technology

Unlike Bell, others using the idea of technology as knowledge have been more explicit in their use of the term. A number of examples are to be found among those whose interest is in the way technology develops. Freeman, for example, bases a discussion of the economics of research and development on a definition of technology provided by Mansfield:-

> Technology is society's pool of knowledge regarding the industrial arts. It consists of knowledge used by industry regarding the principles of physical and social phenomena (such as the properties of fluids and the laws of motion), knowledge regarding the application of these principles to production

> (such as the application of genetic theory to the breeding of new plants), and knowledge regarding day-to-day operations of production (such as the rules of thumb of the craftsmen). (38)

Freeman's object is to make a distinction between the basic knowledge embodied in technology and the knowledge of how to apply it. Thus he argues that new technology may be the result of either the creation of new knowledge or new ways of applying existing knowledge. Hence the broad knowledge-based definition offered by Mansfield suits his purpose.

Johnston is also interested in the way technology develops. He acknowledges the role of external factors in explaining the direction of technological change, but emphasises a dynamic within technology itself. To support his case, he adopts a definition based on Kuhn's concept of paradigm.

> In the context of this paper a technological paradigm is a set of guiding principles accepted by practitioners in a particular field of technology. (39)

A paradigm, he argues, consists of three elements, beliefs and principles (including basic knowledge), exemplars (how the paradigm has operated successfully in the past), and techniques derived from previous experience. A paradigm therefore has an epistemological dimension which provides a framework in which knowledge and applications develop. It also has psychological and sociological dimensions which define both the mental world in which the technologist works and the social norms of that world. These constrain the technologist to define problems and seek solutions for them within the paradigm. Thus, as with Kuhn's scientific paradigm, most technological change consists of new uses and combinations of existing knowledge with major paradigmatic changes occuring only infrequently.

Both Freeman and Johnston, therefore, have broken away from a simplistic identification of technology with machines and industrial processes but their uses of the term still retain a concreteness which allows technological knowledge and its implementation to become the domain and property of particular groups. The meanings they give to technology are far removed from a simplistic identification of technology with machines and industrial processes but they are framed to establish their individual cases and neither has sought, except superficially, to encompass a broader social perspective which could explain the constraints on the direction of change or its wider social significance. The internal momentum of established technology, as I shall argue (40), is one moment of technological change, but a full understanding of that process requires elements not contained in this kind of definition.

Another theme in discussions of how technology develops is the distinction between technology and science. Kuppers makes this distinction on the basis of the 'criteria of relevance' applied by the different institutions responsible for developing new knowledge. Both science and technology, he suggests, apply the same core of knowledge. The differences in their development must therefore be explained by their different objectives in using that knowledge. Hence he argues:-

> Truth on the one hand and efficiency on the other are general relevance criteria for the domains of science and technology. (41)

Within the research environment, the function of criteria of relevance is to select the problems and questions to be resolved and hence the knowledge to be developed. Although technology is defined in terms of knowledge, the emphasis is once again on its application to concrete cases. Thus, Kuppers argues, whether the original requirement is generated internally or externally, the resulting technology must operate in the real world and cannot afford the simplifying assumptions with which science can define experimental situations or mathematical models. Because of this, scientific and technological developments occur within distinct, if related institutional frameworks.

Layton (42) also distinguishes between scientific and technological knowledge in terms of the research communities and institutions which generate it. Science, he argues, values 'knowing' while technology values 'doing'. Such distinctions naturally reinforce the idea that the essence of technology is its practical implementation in concrete form. Even so, like Kuppers, Layton includes a social element in his discussion by arguing that for innovation to occur there must be not only technical capability but also the social will to develop it. In other words the result must be relevant to broader social interests. In spite of his emphasis on practicality, however, Layton limits his definition to fundamental knowledge and excludes technique, that is knowledge about how to use technology.

Thus Layton demonstrates that even where technology is defined as knowledge, the term knowledge itself may result in differing emphases and be ascribed different attributes. Indeed, in another article he uses it in a different way himself. In this case his argument is that science and technology exist as independent intellectual activities, each with a significant component of independent knowledge and that technology cannot therefore be seen simply as the practical implementation of scientific knowledge. Consequently he defines technology as:-

> ...... a spectrum, with ideas at one end and techniques and things at the other, with design as a middle term. (43)

So, like Bell, Layton adapts his use of 'technology', in this case by adding ideas and technique, to fit the context in which he is using it but without offering any global framework to relate their differences.

Technological Knowledge as Power

A different orientation to the idea that the essence of technology is knowledge is offered by those who see it primarily as a resource in power relationships either within organisations or in society as a whole. Frequently this is associated with the role of professionals and experts. The concept of expertise is a natural implementation of the positivist division of knowledge into distinct disciplines and the concept of rationality this implies (44). Rapp presents the argument thus:-

> When discussing the *meaning* of technological actions or the *criteria* of technical decision-making, we cannot avoid a

> 'humanistic' reflection on values. If, on the other hand, the issue is one of determining the range of technically possible *solutions* for a given problem or of predicting the physical *consequences* of any particular technological decision, it is only the scientist or engineer who can completely inform us. (45 - author's emphasis)

Nelkin, however, suggests that the area of conflict is frequently one of uncertainty so that '(t)echnical expertise is a crucial political resource in conflicts over science and technology' (46). Hence the different sides employ the testimony of experts to support their separate cases. Even so, she argues that this reflects an emphasis on technical efficiency as a key criterion in the decision-making process. Thus political decisions, which she sees as ones involving conflicting economic or moral interests, are put 'within the province of experts' (47). Nelkin believes that this is contrary to democratic values and identifies an increasing unwillingness to accept experts' decisions as presenting a growing challenge to technical authority and a reassertion of the democratic process.

Like Nelkin, Commoner (48) also highlights the division of technical knowledge into areas of expertise. The principal consequence, he suggests, is that no single body of knowledge encapsulates the full implications of technological decisions. Inherent faith in technology itself means that the resolution of any problem arising from the unintended consequences of previous technology takes the form of further technological action. This series of 'fixes' is creating an increasingly unbalanced ecological environment which must ultimately lead to a failure of the ecological system. However, it is not possible, according to

Commoner, to avoid this by superficial changes to technology through the democratisation of decision-making. Rather the whole epistemological basis which it represents (including its scientific underpinning) must be changed from reductionism to an holistic view. Commoner believes that this is only possible as part of a change in the nature of industrial societies themselves (49).

ABSTRACT VIEWS - TECHNOLOGY AS EPISTEMOLOGY

Although Commoner still concentrates on the concrete implementation of technology, his argument embraces two elements which hint at its abstract aspects. Firstly, he recognises its epistemological role which goes beyond the direct application of specific knowledge and secondly, he proposes an holistic alternative which recognises that technology is part of an inter-related social whole. Berger et al in a study of modernization demonstrate these characteristics in their view of technology. They define modernization as:-

> ...... the growth and diffusion of a set of institutions rooted in the transformation of the economy by means of technology. (50)

For them this is not simply a question of new institutions; it requires a change in consciouness. Thus, although they do not define technology, it is clear that its essential feature for them is not the machines or methods it provides but the knowledge it employs, and more specifically the way of thinking embodied in that knowledge. They distinguish between the bodies of knowledge required for the execution of a task, and 'the "habits" of thinking that pertain to them' (51). Specific knowledge may not be directly applicable outside a limited 'technical' sphere and yet can involve ways of thinking which may be implemented in a wider context. Hence the knowledge required to find errors in a computer program has a limited application, but the method of ordered investigation it involves might be used in other social contexts such as playing Hide and Seek. In this way, a cognitive style may become part of a symbolic universe in which the knowledge associated with it is not used.

> In so-called developed or advanced industrial societies, in which technological production provides the economic foundation of society as a whole, these carry-over effects are massive. (52)

Thus, they argue, in the process of modernization the consciousness transferred is that associated with the technology which is part of that process (53).

A similar point is made by Mowshowitz:-

> ...... science and technology have furnished more than mere tools for use in dealing with the world; they have fostered a disposition to view the world in a certain way, and to act in accordance with that vision. The tools insist on being used in particular ways. (54)

A general concern with social change leads Mowshowitz to a broad definition of technology:-

> From the viewpoint of social history, technology involves the utilization of energy and materials in controlled situations to modify and organise man's physical and social environment. (55)

He focuses his attention on the significance of information in modern societies. The increasing complexity of these societies and the consequent specialisation and interdependence of their institutions, he suggests, makes information a vital element in co-ordinating activities within them. He describes the way in which complexity has changed the nature of industrial organisations, work and government, and suggests that its implementation in hierarchical structures supports claims to expertise and the need for centralized control. Thus he concludes, computers, as one specific implementation of technology, are simply tools in the 'subtle process of democratizing psychic violence' (56).

One of the best known exponents of the view that technology is a way of thinking which dominates industrial societies is Jacques Ellul. He ignores its concrete implementation entirely and rejects the term technology because of its use by others to represent it. He talks instead about technique.

> The term *'technique'*, as I use it, does not mean machines, technology, or this or that procedure for attaining an end. In our technological society, *technique* is the *totality of methods rationally arrived at and having absolute efficiency* (for a given stage of development) in *every* field of human activity ...... Technique is not an isolated fact in society (as the term *technology* would lead us to believe) but is related to every factor in the life of modern man; it affects social facts as well as all others. (57 - author's emphasis)

Ellul recognises that technique, in the sense of applying appropriate means to achieving specified ends, has always been a human characteristic. What concerns him is a change in its nature during the development of industrial societies. In its new form, he argues, it is concerned with finding a single, 'best' method in each situation and with applying this approach to more and more areas of social life to the point where it becomes the epistemolgy of all action.

Ellul identifies the characteristics of technique as:-

a) the assumption that there is always one best way,

b) self-augmenting, its state at any time implying the need for further development,

c) being an integral part of society,

d) a whole whose parts are inextricably linked in a way that makes it impossible to dispose of individual ones,

e) universal, not limited by the racial, political or economic characteristics of a society,

f) being the standard of judgement rather than its object,

g) being autonomous of social constraints and circumventing natural ones.

Once the point is made that technology is inherent in society and imbued with social values, anyone offering an alternative must either justify a claim that what they propose is genuinely value-free, or accept that new technology will imply new values. Habermas takes the former line (58). The latter alternative is characterised by Edge's comment that:-

> AT (alternative technology) began with the realization that advanced, capital-intensive Western technology was 'non-neutral': but the alternative is *not* a 'neutral' technology - it is a technology *committed to different values.* (59 - author's emphasis)

Ellul evades the need to make this choice by arguing that his work is descriptive rather than prescriptive and makes no judgement on the situation he is describing.

However, whilst Ellul claims to be neutral in the debate on technological domination, members of the Frankfurt School have developed it as a cornerstone in their political stance. An indication of their line of argument is given by Heidegger (60). He recognises what he calls the 'instrumental or anthropological' concept of technology but emphasises that its essential nature in modern societies is as a way of 'revealing'. He distinguishes therefore between traditional technology which employed nature in the forms in which it presents itself and modern technology which changes nature in order to exploit it. Like Ellul, he sees this as a fundamentally new way of viewing the world with significant consequences for the discussion of technology.

> Because the essence of technology is nothing technological, essential reflection upon technology and decisive confrontation with it must happen in a realm that is, on the one hand, akin to the essence of technology and, on the other, fundamentally different from it. (61)

Heidegger believes that the appropriate area of confrontation is art.

Perhaps the most politically influential exponent of the Frankfurt School's argument has been Herbert Marcuse, at one time a student of Heidegger (62). His ideas were particularly popular with participants in the student movements of the 1960's. Marcuse describes his position as follows:-

> The analysis is focused on advanced industrial society, in which the technical apparatus of production and distribution (with an increasing sector of automation) functions, not as the sum-total of mere instruments which can be isolated from their social and political effects, but rather as a system which determines a priori the product of the apparatus as well as the operations of servicing and extending it ......
> Technological rationality has become political rationality. (63)

The habit of thinking involved in modern technology, he argues, has come to dominate all other forms of thinking in industrial societies. By becoming the measure of validity, it has been able to stifle all other epistemologies. Hence when MacIntyre (64) criticises his argument for being 'only loosely supported by an appeal to evidence', Marcuse might respond that MacIntyre is making the very assumption as to what constitutes a valid argument which Marcuse is criticising. Marcuse believes that the only solution to the domination of technological values is their complete replacement. However, he is so convinced of the domination of technological thinking that he sees little hope of establishing an alternative except through the mechanism of 'utopian' thought which breaks through the one-dimensional technical world to negate the negation it represents.

Marcuse's argument is essentially philosophical, but it is given empirical expression in Noble's 'America by Design' (65) which is strongly influenced by the ideas of the Frankfurt School. Noble's object is to explain the failure of the proletarian revolution in the United States which he does in terms of the domination of technological thinking. His introduction summarises the argument as follows:-

> This social process called technology, moreover, does not exist simply for itself, in a world of its own making. It is, rather, but one important aspect of the development of society as a whole. Since those who comprise society are at the same time the human material of which technology is composed, technology must inescapably reflect the contours of that particular social order which has produced and sustained it. And like any human enterprise, it does not simply

> proceed automatically, but rather contains a subjective element which drives it, and assumes the particular forms given it by the most powerful and forceful people in society, in struggle with others ...... The primary thesis of this book is that the history of modern technology in America is of a piece with that of the rise of corporate capitalism. (66)

Noble's argument is directed therefore at a specific technological society and not at modern technology as a general category. He develops his argument by demonstrating how the American science-based industries (especially the chemical and electrical industries) were increasingly dominated during their formative stage by a few large corporations which were able to dictate what research was done, what standards were adopted and the content of technical education. Technology did not develop, therefore, from an inner imperative, but was steered in directions which corresponded with the interests of a dominant group. Noble is not proposing a conspiracy theory; he is arguing rather that the nature of capitalism constrains choices in particular directions, in this case making certain technological decisions more likely than others.

By the end of his book, Noble is clearly talking about technology primarily as a way of thinking (67). Unlike Ellul, his concern is not with the dominance of technological thinking in itself but with the way it reinforces the dominance of capitalism, in particular that those responsible for developing and using industrial technology have been trained to do so in a way which furthers that dominance. This is particularly true in the science based industries which are not grounded in the traditional milieu of small entrepreneurs each developing his/her own technical knowledge.

> From the outset, therefore, the engineer was at the service of capital, and, not suprisingly, its laws were to him as natural as the laws of science. (68)

Within the limits of the evidence he offers, Noble makes a strong case, but he draws that evidence from only one country and for a period ending in 1930. He does not deal therefore with national differences in capitalist development nor with the substantial changes in the nature of both capitalism and science-based industry since 1945. Because of his concentration on the abstract nature of technology he does not make clear the implications of the situation he describes for the machines and processes which are developed. He does point out that:-

> Even in his strictly technical work the engineer brought to his task the spirit of the capitalist. His design of machinery, for example, was guided as much by the capitalist need to minimize both the cost and the autonomy of skilled labour as by the desire to harness most efficiently the potentials of matter and energy. (69)

However, he makes it clear that his main concern is with technology as an 'essentially human phenomenon' and not its concrete forms. Even so, this comment strikes a discordant note within the context of his overall argument. The implication of his statement is that technology involves a 'technical' element, the most efficient use of the potentials of matter and energy, and a social one, the minimization of cost and labour autonomy. What he does not acknowledge is that efficiency is itself a measure of the results of a process and is therefore defined in a specifically capitalist/technological way. The notion of efficiency he uses therefore embodies the very way of thinking he is criticising.

If this implication were carried through to his main theme it would leave him in a position similar to Gendron whereas Werskey (70) includes him with Marcuse and Braverman as providing an effective critique of the vulgar Marxist neutrality of technology thesis by identifying the critical feature of technology as its role in giving a theoretical underpinning to capitalism. However his concept of technology, according to Werskey, is still essentially 'technicist' and fails to embrace Marx's broader concept of 'forces of production'. As a result he shares Marcuse's pessimism about the possibility of undermining capitalism and is:-

> ...... (tauto-)logically obliged to deduce that there is no (longer?) contradiction, only correspondence, between the forces and relations of production that have come to prevail in the United States. (71)

SUMMARY

The use of 'technology' to refer to the fundamental epistemology or ideology of a society, takes this review close to the abstract extreme of the continuum being explored. At this point the specific forms taken by technology and the results of technological action, which were the concern of other uses of the term, are now seen as insignificant compared with its broader social role. Although far from comprehensive, therefore, this review has demonstrated the range of meanings attributed to technology and the numerous shadings of emphasis between them. It has located the different uses on a concrete/abstract continuum where those tending towards the concrete pole identify technology with machines, processes and knowledge (in a form where it can be the property of specific individuals or groups) and those favouring an abstract interpretation are principally concerned with technology as an epistemology.

The object of this chapter has not been to make a detailed examination of these various views, but to indicate the range of meanings, implicit and explicit, and the variety of their contents. Many of the uses described exclude attributes of technology which are to be found in others and in some cases the attributes ascribed to technology by different authors are contradictory. Frequently this can be explained by a definition being tailored to the argument of which it is part. However, the object of the chapter has not been to criticise any particular use in detail, but to illustrate a general argument that none is sufficiently broad to encompass all those attributes which severally they ascribe to technology. Even those which acknowledge the breadth of meaning which can be given to the term, emphasise either its concrete or abstract characteristics, and none has demonstrated the significance of the two for each other in a useful synthesis of their contrasting attributes.

Having demonstrated this variety and the concrete/abstract dichotomy, the next objective of this thesis is to construct a basis for a comprehensive synthesis of these two basic orientations. That task will proceed in two stages. Firstly it will examine the potential for such a synthesis in the positivist principles which typically underlie the concrete conceptions of technology described above. This approach will be shown to be inadequate for the purposes of the thesis and will be rejected. The second stage therefore will seek to construct the synthesis from a non-positivist position. The work of a number of writers will be used to derive a comprehensive conceptualisation of technology which takes account of both its concrete and abstract elements. The remainder of the thesis will then demonstrate the understanding to be afforded by that synthetic concept.

NOTES FOR CHAPTER 2

1. Winner L. 'Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought', 1977, MIT Press, Cambridge Mass, p. 10

   Technology is not the only concept to experience this phenomenon, see for example Larrain J. 'The Concept of Ideology', 1979, Hutchinson, London.

2. The confusion over formal uses of 'technology' is complicated by the use of other terms dealing with similar phenomena, for example 'technical' (Aron R. 'Progress and Disillusion: the Dialectics of Modern Society', 1972, Penguin, Harmondsworth), 'technics' (Mumford L. 'The Myth of the Machine: Technics and Human Development', 1967, Secker and Warburg, London), and 'technique' (Ellul J. 'The Technological Society', 1965, Jonathan Cape, London). For the purpose of this survey these have been treated as references to the same global phenomenon whilst recognising the authors' reasons for using different terms.

3. Aron R. 1972 op cit. p. 15

4. Rapp F. 'Analytical Philosophy of Technology', 1981, D Reidel, Dordrecht

5. Ibid. p. 19

6. Gendron B. 'Technology and the Human Condition', 1977, St. Martin's Press, New York

7. Sayles L.R. 'Behaviour of Industrial Work Groups', 1958, Wiley, New York

8. Silverman D. 'The Theory of Organisations', 1970, Heinemann, London, p. 104

9. Blauner R. 'Alienation and Freedom: The Factory Worker and his Industry', 1964, University of Chicago Press, Chicago

10. Woodward J. 'Industrial Organisation: Theory and Practice', 1965, Oxford University Press, London

11. Perrow C. 'Complex Organisations: A Critical Essay', 1972, Scott Foresman, Glenview, p. 168

12. Gallie D. 'In Search of the New Working Class', 1978, Cambridge University Press, Cambridge, p. 34

13. Rose M.J. 'Industrial Behaviour - Theoretical Developments since Taylor', 1975, Allen Lane, London.

Organisational theory has proved a fruitful ground for examining theoretical assumptions, see for example Burrell G. and Morgan G. 'Sociological Paradigms and Organisational Analysis', 1979, Heinemann, London.

14. Pfeffer J. 'Organisational Design', 1978, AHM, Arlington Heights Ill.

15. e.g. Edwards R.C. et al (Eds.) 'Labour Market Segmentation', 1975, D.C. Heath and Co., Lexington Mass. and Woodward J. 'Industrial Organisation: Behaviour and Control', 1970, Oxford University Press, London

16. Pfeffer J. 1978 op cit. pp. 94-5

17. Godelier makes a similar comment with regard to one commonly adopted definition of economics:-

> Here, however, we come upon a paradox, since the very subject-matter of economics as defined by the majority of present-day economists is nothing else than the subject-matter of the formal theory of purposive action (Godelier M. 'Rationality and Irrationality in Economics', 1972, New Left Books, London, pp. 12-13)

18. Price D.J. 'Science and Technology: Distinctions and Interrelationships' in Barnes B. (Ed.), 'Sociology of Science', 1972, Penguin, Harmondsworth, p. 172

19. Lawless E.W. 'Technology and Social Shock', 1977, Rutgers University Press, New Brunswick, p. 8

20. see for example Nelkin D. 'Science, Technology, and Political Conflict: Analyzing the Issues' in Nelkin D. (Ed.), 'Controversy: Politics of Technological Decisions', 1979, Sage, London

21. Ackroyd C. et al 'The Technology of Political Control', 1977, Penguin, Harmondsworth

22. Ibid. p. 19 (footnote)

23. Ibid. p. 20

24. Gendron B. 1977 op cit. p. 236

25. Ibid. p. 23

26. Elliott D.A. & R. 'The Control of Technology', 1976, Wykeham Publications, London, pp. v-vi

27. Ibid. p. vii

28. Ibid. p. 3

29. Ibid. p. 49

30. Fores M. 'Technological Change and Innovation' in Bowe C. (Ed.), 'Industrial Efficiency and the Role of Government', 1977, HMSO, London

31. Freeman C. 'Economics of Research and Develpment' in Spiegel-Rosing I. & Price D.J. (Eds.), 'Science, Technology and Society', 1977, Sage, London, p. 225

32. Bell D. 'The Coming of Post-Industrial Society', 1974, Heinemann, London

33. Ibid. pp. 175 & 176

34. Ibid. p. 11

35. Ibid. p. 212

36. Ibid. p. 112

37. Ibid. p. 196

38. Freeman C. 1977 op cit. p. 225

39. Johnston R.D. 'The Internal Structure of Technology' in Halmos P. (Ed.), 'The Sociology of Science', 1972, University of Keele, p. 122

40. see chapter 4.

41. Kuppers G. 'On the Relation between Technology and Science' in Krohn W. et al (Eds.), 'The Dynamics of Science and Technology', 1978, D Reidel, Dordrecht, p. 118

42. Layton E. 'Conditions of Technological Development' in Spiegel-Rosing I. & Price D.J. (Eds.), 'Science, Technology and Society', 1977, Sage, London

43. Layton E. 'Technology as Knowledge' in *Technology and Culture* Vol. 15/1 Jan. 1974, pp. 37-8

44. see chapter 3 for a discussion of this characteristic of positivism and chapters 7 and 8 for one on expert computer systems and their implications.

45. Rapp F. 1981 op cit. p. 3

46. Nelkin D. 1979 op cit. p. 15

47. Ibid. p. 9

48. Commoner B. 'The Closing Circle', 1972, Jonathan Cape, London

49. Dickson offers a variation of this view which begins from a need to radically change society and recognises the similarly radical consequences for technology: see Dickson D. 'Alternative Technology', 1974, Fontana, London.

50. Berger P. et al 'The Homeless Mind', 1973, Random House, New York, p. 9

51. Ibid. p. 15

52. Ibid. p. 39

53. Berger et al are discussed further in chapter 3.

54. Mowshowitz A. 'The Conquest of Will', 1976, Addison-Wesley, Reading Mass., p. 8

55. Ibid. p. 10

56. Ibid. p. 245

57. Ellul J. 1964 op cit. p. xxxiii

58. This will be discussed in chapter 4

59. quoted in Lipscombe J. & Williams B. 'Are Science and Technology Neutral?', 1979, Butterworths, London, p. 37

60. Heidegger M. 'The Question Concerning Technology' in Krell D.F. (Ed.), 'Martin Heidegger: Basic Writings', 1978, Routledge & Kegan Paul, London

61. Ibid. p. 317

62. It must be recognised that the Frankfurt School encompasses a number of expressions of this view. See for example Habermas J. 'Toward a Rational Society', 1971, Heinemann, London

63. Marcuse H. 'One Dimensional Man', 1972, Abacus, London, pp. 13 & 14

64. MacIntyre A. 'Marcuse', 1970, Fontana, London

65. Noble D.F. 'America by Design', 1977, Knopf, New York

66. Ibid. pp. xxii-xxiii

67. see Werskey G. 'Review of "America by Design"' in *Radical Science Journal* No. 8, 1979

68. Noble D. 1977 op cit. p. 34

69. Ibid. p. 34

70. Werskey G. 1979 op cit.

71. Ibid. p. 115

CHAPTER 3

THE POSSIBILITY OF A POSITIVIST SYNTHESIS

THE SEARCH FOR A NEW CONCEPT

The last chapter surveyed a number of uses of 'technology' and found that each emphasised either its concrete or abstract attributes. This chapter begins the search for a conceptualisation which synthesises these alternative orientations. To this end it offers a critical assessment of the possibility that this synthesis can be based on positivist principles. In particular, it discusses the mechanistic epistemology derived from positivism which underlies the commonsense meanings given to technology in modern industrial societies and those discussed in the last chapter which displayed an inclination to its concrete attributes.

This discussion will be developed in two phases. Firstly, it will describe various facets of mechanistic thinking and demonstrate their mutual support for each other. Subsequently, the limitations this imposes on the possibility of a synthesis of the concrete and abstract aspects of technology will be identified. Two central points will emerge from this discussion. The first is the key role in mechanistic thinking played by its assumption that any whole can be fully defined in terms of discrete components and their relationships within the whole. This, it will be argued, excludes the possibility that the whole may have attributes or potentials which cannot be identified in this way and are uniquely relevant to the composite whole. The second point to result from this discussion is the assumption in positivism, based on its claim to objectivity, that it constitutes the only valid basis for obtaining and assessing scientific knowledge. This assumption will be seen to preclude the possibility of overcoming the limitations identified in the first point. As a result, positivist/mechanistic principles will not be found to offer a basis for a synthetic concept of technology.

PRINCIPLES OF THE POSITIVIST VIEW OF TECHNOLOGY

The Idea of Wholes and the Resolution of Complexity

Although methods and terminology derived from the mechanistic concept of technology have become commonplace in popular literature and conversation, that concept is far from simplistic. On examination it will be found to consist of a number of principles and assumptions which together contribute to a complex entity. Berger et al (1) list its main elements as:-

a) the idea that wholes can be broken into discrete components,
b) the idea that a whole can be (re)constructed from a number of parts in a rational, controllable and predictable way,
c) the assumption of maximisation i.e. most gained for least effort is best,
d) the separation of means from ends,
e) the abstraction of action into an end in itself.

The principle of wholeness contained in the first two elements is the key to mechanistic thinking. It states that any totality can be reduced to a number of discrete and basic elements whose relationships with each other, and with the whole, can be fully and precisely defined. The corollary of this principle is that the same parts can be reassembled so that the original whole is reconstructed, or that they can be rearranged to produce a predictable alternative. There is no place, therefore, for the idea that a whole may embody elements which are unique to itself and cannot be derived from its constituents, or which are context dependent in any fundamental sense. The whole must always be a simple aggregate of its parts.

This approach is typified by functional engineering where individual components, with known inputs and outputs, are arranged in different sequences to create 'machines'. These may in turn become part of larger machines or processes. The division of labour applies this same principle to processes involving people. By reducing tasks to a series of separate operations, individuals may specialise in a limited part of the whole process. Like the elements of a machine, therefore, they need only be concerned with their immediate inputs and outputs and have no need to understand the process in its entirety.

This particular view of wholes gives rise to a number of other notions whose integrity is dependent on its assumptions. It leads, for example, to a specific view of complexity and methods of dealing with it. Mechanistic thinking does not, in itself lead to complexity; indeed one of the criteria for judging a scientific theory is its simplicity (2). None-the-less, so many features and institutions of modern Industrial societies are both larger and more complex than those in other types of society, that according to Mowshowitz-:

> Contemporary society exhibits a prodigal degree of complexity in its division of labour, interdependent functions, and large, mobile populations. Our economic, political, and cultural affairs are conducted as large-scale enterprises which require specialized structures for coordination and control. (3)

Furthermore, as these structures develop and create new demands for coordination, so they make possible even greater size and complexity through what has become a self-perpetuating process.

Hence Pollard (4) identifies the growth in the size of industrial units as a major stimulant to the development of new management techniques. Mowshowitz highlights the political implications of this same tendency.

> In the context of social development, the argument from complexity is used to support the contention that consolidation of power in centralized bureaucracies is both natural and essential to the preservation of society. This justification for the concentration of authority feeds on the widespread acceptance of the expert as the arbiter of complex problems. (5)

The principal method applied in the mechanistic resolution of complexity is that of 'divide and conquer'. In other words, a complex situation is reduced to a series of simpler ones whose individual resolution will amount to a total solution of the more complex whole. This approach is clearly grounded in the concept of wholes identified above without which it would not be possible to assume that the original whole can be reconstructed. In the same way, the proliferation and increasing complexity of knowledge in industrial societies has led to specialisation, the demarcation of academic disciplines and the establishment of areas of expertise.

The mechanistic resolution of complexity therefore gives rise to a specific notion of 'problem' which limits the knowledge and expertise applicable to any situation. Identifying a problem brackets out questions and makes assumptions which define a limited search area for its solution. Kuhn (6) uses the concept of paradigm to describe how the formulation of 'problems' in science is constrained within a specific set of assumptions with significant consequences for the knowledge resulting from their resolution. Others show how the concept of 'problem' is employed by sources external to science in determining directions for research (7). In the social sciences for example, the research which attracts funding is that directed towards solving social 'problems' such as racial unrest, industrial performance and crime. Here, as in the natural sciences, the formulation of the problem may mask the assumptions being made. Thus if unemployment is defined as a problem, the measure of a solution is its ability to reduce the numbers of unemployed and yet this excludes consideration of alternatives which question the definition of unemployment as a problem, for example the argument that what is needed is a policy for increased leisure (8).

Efficiency

This approach to complexity is supported by another feature of the mechanistic view which Berger et al call 'the assumption of maximisation' and which I shall call 'efficiency'. The term efficiency is derived directly from mechanics where it is applied to any process transforming energy from one form to another. In such a process some of the force input is absorbed in doing the work of transformation so that the energy embedded in the output is necessarily less than that originally input. Efficiency is a measure of the energy lost and is defined as the ratio of useful work done to the total force applied. In riding a bicycle, therefore, this would be the ratio of energy expended to the distance travelled and pedalling with the brakes on would be singularly inefficient.

In its broader role within the mechanistic epistemology, however, the term efficiency has undergone a significant change. This is characterised in market economics by the fact that output is no longer measured in terms of useful work done. Instead, the measure is the market value of the resulting commodity and the output of a process is expected to increase in value not decrease. Efficiency therefore becomes the ratio between the change in the market value of the output and the costs of its production. The role of management is to manipulate these variables to maximise efficiency, that is the increase in value, for example by changing labour costs through the use of a new machine or a change in rates of pay.

Applying this concept of efficiency to the division of labour was seen by Babbage (9) to provide a number of benefits:-

a) the costs of training are reduced because each worker only needs knowledge of a limited part of the production process,

b) the individual worker will perform a task better, i.e. more productively, because he/she is skilled in only one operation,

c) the less skilful operations can be performed by workers paid the appropriate rate for the level of skill required rather than craftsmen being paid for work not requiring their skills.

Babbage's main preoccupation, as we shall see in chapter 5, was with the construction of calculating machines. In this activity, mathematics and engineering provided the principles on which his designs were based. In his discussion of industrial organisation, the application of the same mechanistic 'principles of generalization' is quite explicit:-

> The present volume may be considered as one of the consequences that have resulted from the Calculating-Engine, the construction of which I have been so long superintending. (10)

<u>Quantification</u>

Directly related to the concept of efficiency is that of quantification. As Sklair notes in discussing the measurement of efficiency in terms of an increase in monetary value.

> This type of cost-benefit analysis ...... is consistent with a basic tenet of techno-economism, namely that all worthwhile things are measurable and all important problems can be solved by its methods. (11)

Hence Giddens comments that:-

> In Weber's view, rational book-keeping constitutes the most integral expression of what makes the modern type of capitalist production dissimilar to prior sorts of capitalistic activity such as usury or adventurers' capitalism. The circumstances which Weber details as necessary to the existence of capital accounting in stable productive enterprises constitute those which Weber accepts as the basic prerequisites of modern capitalism ...... (12)

Double-entry book-keeping typifies the disposition to quantify both as a monetary measure of efficiency and as a means of managing large and complex organisations. It is no coincidence that Babbage was both an advocate of the principles of industrialism and a founder member of the Statistical Society in England.

This concern with quantification is rooted in the origins of mechanistic thinking in the natural and physical sciences. However the significant feature in the present context is the disposition to apply it to areas of study with no direct relationship to this origin. Boudon, for example, believes that he can justify its use in the social sciences by an appeal to the 'scientific' status it denotes.

> In what follows, we have done our best to illustrate one of the essential functions of mathematics - perhaps *the* essential function - which is *clarification*. When a discipline achieves scientific maturity, this is almost always correlated with at least partial mathematization. (13 - author's emphasis)

Rationality, Prediction and Control

Not all organisations in industrial societies are engaged in commodity production with its direct measure of efficiency in terms of monetary value. However, their efficiency is still assessed, if not quantitatively, then in terms of their rationality. The mechanistic concept of rationality is concerned with the application of appropriate means to the achievement of ends and is encompassed in the fourth principle listed by Berger et al. For action to be rational the actor must have a clear objective and choose the most efficient means of achieving it. This always assumes that the actor can predict the consequences of the action proposed. Positivist science formalises this rationality in axiomtic causal relationships in which the result of changing any one parameter can be calculated in terms of its effect on the others. However this ability to predict the consequences of change is not an end in itself. It is one step towards being able to control the process of change and to manufacture desired situations. Indeed some would argue that the facility to control is a necessary component of any knowledge claiming to be scientific (14).

When mechanistic rationality is applied outside the natural and physical sciences these elements of predictability and control still feature. The introduction of the factory system had the objective of regulating the quality and quantity of production in a way which was not possible with domestic workers. Its development through the division of labour has provided a means of both predicting the level of output and controlling the labourer (15), for example through the concentration of information in the hands of managers (16).

Organisations may also attempt to exert control on external factors, for example, by political lobbying, advertising and sponsorship of sympathetic individuals and organisations. The same objective is also manifest in the tendency towards company mergers and the growth of multinationals. Two types of merger can be explained directly in terms of the increasing external control they offer. On the one hand, where companies operating in the same market merge, there is a tendency to monopoly which minimises the uncertainty of competition. On the other hand, the integration of companies at different stages in the same chain of production aims to reduce uncertainty by controlling either suppliers or markets. Another aspect of control and risk minimisation in industry is the increasing role of the state in the economy where it has been both a financier and a guaranteed market without which some risk ventures may not have been undertaken. The state also reduces costs to industry by redistributing social costs such as pollution and training (17).

In maximising their ability to predict and control, organisations are applying the mechanistic concept of rationality by ensuring that the means they adopt are those most likely to achieve their end. Thus if:-

> ...... one understands rationality to be the effective, logical ordering of technological parts, then systems which seek to control their own ends are the epitome of the rational process. (18)

The part played by the assumption of control in the cognitive style of industrial societies is also demonstrated in relationships between people and nature. Mechanistic thinking encourages the view that nature exists to meet human needs and should, where necessary, be changed to achieve this. Much of the impetus for technological innovation has been derived from the urge to 'control', 'tame' or 'modify' nature. A central feature of the industrial revolution in ninteenth century Britain was increasing control over sources of mechanical power which replaced the uncertainty of wind, water and the direct application of human muscle-power with the steam engine, whose power and performance were both predictable and controllable.

However, application of the mechanistic principle of control has not been limited to industrial machinery or processes; it has also been applied to relationships between people, converting '...... spontaneous and unreflective behaviour into behaviour that is deliberate and rationalized.' (19). Thus job training often involves instruction in how to deal with people, and bodies of knowledge have developed around the notion of social engineering. Work on artificial intelligence also assumes a mechanistic model of human expertise and thought processes (20). The mechanistic rationality and its predilection to control have, therefore, become deeply ingrained in the social fabric of industrial societies. Indeed, as Winner (21) points out, fears of autonomous technology arise precisely because of the belief that people should be able to control those things they have created.

THE POSITIVIST ASSUMPTION OF OBJECTIVITY

This discussion has not been concerned with the various forms of positivism, nor has it engaged in theoretical analysis and critique. Rather it has identified the key components of the positivist view of technology in order to assess the practical possibilities of constructing a synthetic definition from it (22). This discussion has concerned itself, therefore, not with the philosophical principles of positivism, but with the mechanistic paradigm derived from them. It is this paradigm which informs not only many formal uses of 'technology', but also its commonsense meaning in modern industrial societies.

This mechanistic concept of technology has not always been the dominant commonsense view. Aristotle, for example, represented technology as knowledge of both how and why things occur. Only in more recent times has a distinction been made between technology and science, that is between principles and their manifestation in the world, with the result that the role of technology has been redefined as the practical application of the knowledge resulting from science. Layton (23) traces this schism to Galileo whose main contribution to science, he suggests, was to show that all machines are based on the same principles of force and that these principles can be expressed mathematically (24). Thus science has become the formal investigation and expression of the axiomatic laws of nature whose existence is unaffected by their application.

During the seventeenth century this idea of an objective and mechanistic world was established philosophically by Pascal and scientifically through the success of Newton's physics. The mechanistic view banished mankind from the centre of the world stage and, at the same time, led to a differentiation between the natural forces which are the object of scientific study and final causes which are the subject of faith and religion. Burtt gives some indication of the extent and significance of the change this represented when he says that it led to new conceptions of reality, causality and the human mind and that:-

> These changes have conditioned practically
> the whole of modern exact thinking. (25)

A more recent shift in the meaning of technology was discussed in the work of some of the writers considered in the last chapter who differentiated between traditional and modern technology (26). The year 1945 is often taken to be a critical point in this transition. Prior to that date there was ample evidence of the increasingly significant role of mechanistic principles both as a way of thinking and in their concrete application, but the Second World War concentrated and accelerated many of these developments (27). Among the resulting changes was the establishment or rapid expansion of industries based on science and technology such as electronics, motor vehicles, aircraft and chemicals. Machines became part of the everyday working experience of an increasing number of people both on the factory floor and through the development of domestic and office machinery such as washing machines and computers. At the same time there was an increase in the size and complexity of organisations especially those in industry and the state.

However, the main consequence discussed by authors like Heidegger and Ellul is not the concrete implementations of technology, but the final establishment of the mechanistic concept of technology, and its underlying positivist principles, as the cognitive style of modern industrial societies. The cognitive style of a society embodies the principles applied to the acquisition and application of knowledge. In some societies there may be different styles for different spheres of social activity such as religion, science and personal interaction. This shift in the meaning of 'technology', however, is typically seen to involve the infusion of mechanistic thinking into every sphere of society.

It is possible to identify numerous ways in which this cognitive style pervades the social life of its host societies. Lipscombe and Williams (28) demonstrate how everyday metaphors reflect an 'engineering mentality' and Ziman (29) shows how its assumptions are built into education. The work of E.W. Taylor (30) assumed that workers could be treated like machines, and although the application of his ideas has lost some of its original starkness, Rose (31) argues that they still represent the basis of management thinking. On a wider scale Habermas (32) believes that the centralised state has had to rely increasingly for its legitimation on its claim to fulfil the role of technical expert in the maintenance of the complex social system.

Underlying this pervasive tendency within mechanistic thinking is the assumption, inherent in positivism, that it promotes knowledge which is free of subjective and socially imposed values. Consequent on this assumption is a claim to be the only valid basis for obtaining and assessing 'scientific' knowledge. Hence the various facets of the mechanistic model derive their legitimacy from an assumed independence from normative influences and the corresponding assumption that they represent the natural mode of human thought. This principle of neutrality arose originally both from the political expediency of identifying distinct spheres of concern for science and religion (33) and from the desire of scientists to represent their findings as objective truths of the natural world. Hence Lipscombe and Williams quote Galileo as saying that:-

> ...... the conclusions of natural science are true and necessary, and the judgement of man has nothing to do with them. (34 - emphasised in original)

The translation of this principle to technology allows the knowledge used in its construction to assume an objective status whilst the ends to which it is applied may still be socially determined. The idea of neutrality has been translated almost without modification, therefore, from its original application in the physical and natural sciences to every sphere of knowledge which invokes mechanistic thinking.

This argument is developed by Berger et al in 'The Homeless Mind' (35) in which they distinguish between the knowledge relevant to a particular task and the cognitive style associated with it. The significance of this distinction is that while technical knowledge may not be transferable from its immediate domain of application, its cognitive style may be carried over into other spheres of activity. According to Berger et al this is what has happened with the cognitive style of 'technological production' which has been subject to massive carry over from work situations, where it is appropriate, into non-work situations where it is not. Thus it has become part of the symbolic universe of people not directly applying the knowledge associated with it and has become an established world view with its own dynamic independent of specific social institutions.

Thus we see that the mechanistic concept of technology is grounded in a set of interrelated concepts which together define appropriate means of acquiring and expressing knowledge. They also define the status of that knowledge and the reality which it represents. Whilst Berger et al are critical of the transfer of mechanistic thinking to non-work situations, they accept its validity in technical and production activities (36). The purpose of this chapter, however, is to examine that assumption. As the last chapter showed, the positivist/concrete view has typically led to a concrete conception of technology. The question to be answered, therefore, is whether it can also account for the abstract nature of technology and therefore produce a comprehensive understanding of it.

LIMITATIONS OF THE MECHANISTIC VIEW OF TECHNOLOGY

Overview

The following discussion will argue that the principles of mechanistic thinking described above embody limitations which preclude them as a basis for a synthetic concept of technology. The discussion is presented in three parts. Firstly, it offers evidence from the sociology of knowledge that positivist assumptions about the special status of scientific knowledge, arising from its claim to objectivity, cannot be sustained in practice because the methods used to obtain that knowledge employ the same cultural resources as other forms of social interaction and their results must therefore be ascribed a similar status. The second part of the discussion illustrates that not only do the methods of scientific research not conform to positivist principles, but that the resulting knowledge may itself question the validity of the mechanistic model of nature. The final part then shows that inherent in the principles of positivism, and its mechanistic derivative, is the assumption that only knowledge resulting from the application of its principles and conforming to them is valid scientific knowledge. The contradiction between this assumption and evidence from the sociology of knowledge and the results of scientific research constitutes the case for rejecting positivism as a basis for the construction of a synthetic concept of technology.

The Sociological Evidence

Sociological studies of scientific knowledge are especially significant in identifying the limitations of positivist/mechanistic principles because they address a subject which both epitomises their application and provides the basis of their relevance to technology. Mulkay (37) identifies two contrasting views presented by the sociology of science. The first he calls the 'Customary View of Science'.

> This is the dominant perspective which treats science as a special sociological case. Scientific knowledge is regarded as epistemologically unique - as consisting basically of observation statements which have been firmly established by the controlled, rigorous procedures of scientific method. The corpus of certified scientific knowledge is thought to represent, with increasing accuracy and completeness, the truth about the physical world. (38)

The second view is a result of the growing evidence which contradicts the first and presents:-

> ...... an alternative perspective which argues that the procedures and conclusions of science are, like all other cultural products, the contingent outcome of interpretive social acts. It is argued that the empirical findings of science are intrinsically inconclusive and that the factual as well as the theoretical assertions of science depend on speculative and socially derived assumptions. It is also suggested that the general criteria by which scientific knowledge-claims are assessed (such as consonance with the evidence, replicability, and the like) have no meaning until they are interpreted in terms of the scientists' particular intellectual commitments and in relation to specific interpretive and social contexts. (39)

Hence, this new view rejects the positivist assumption of special status for the content of scientific knowledge and its consequent exclusion from sociological analysis. The key to this rejection is the treatment of knowledge-claims and the assumption that the criteria used in assessing them are objective and consistent in every case. This assumption is based on the belief that the subject matter of science is a physical world whose truths can be progressively revealed by the process of scientific examination. However, as Mulkay argues, claims to scientific knowledge are typically made for theoretical interpretations of observations rather than the observations themselves and yet the meaning of those observations may be subject to different interpretations. We cannot say, therefore, that scientific knowledge is 'based on a direct representation of the physical world' because there is 'nothing in the physical world which uniquely determines the conclusions of [the modern scientific] community'. As a result, it 'necessarily offers an account of the physical world which is mediated through the available cultural resources; and these resources are in no way definitive' (40). Once this foundation is removed from science, Mulkay suggests, there is no reason to treat the knowledge it offers as a special category which is not amenable to sociological analysis.

This argument has a direct relevance to the discussion of technology in that the fundamental knowledge on which technology is based is attributed the same status as scientific knowledge and may even be presented as evidence of the validity of that knowledge (41). Mulkay vigorously challenges this second claim, arguing firstly, that there is no necessary link between successful technology and basic scientific knowledge, and secondly, that even where such a link does exist, this does not grant any validity to the scientific knowledge. However, positivist science is obliged to reject this argument because the methods by which most scientific observations are made themselves involve the use of technological instruments. If these were not based on sound scientific principles, then clearly their results could not form the basis of scientific knowledge. Indeed, some of the case studies reported by Mulkay, which support the new sociology of science, demonstrate quite clearly that negotiation over the adequacy of scientific developments is often really about the adequacy of the technological instruments being used. There is even a case for arguing that modern scientific research requires such complex technology that what is really being assessed in many cases is the technology itself. Thus, Pinch points out, the instruments which todays scientists treat as unquestioned 'black boxes' are themselves the outcome of a process of negotiation and closure. Thus:-

> In a way the black boxing of instruments can be seen to be what scientists are aiming towards. Problematic social links between an evidential context and an instrument not only become frozen but such instruments can be used to establish new evidential contexts or make further links in the networks of evidential contexts and pieces of apparatus. (42)

Two examples cited by Mulkay are based on studies by Collins. The first concerns the development of a particular type of laser called a 'TEA laser'. The study of its development shows how, in the initial stages, interaction between various groups attempting to construct a laser had to be personal rather than formal because their members could not formulate clear 'principles of construction' (43) which if adopted would enable the replication of previous results. Indeed, some scientists who successfully constructed a laser were still unable to communicate how their results could be reproduced. In the second example Collins discusses research into gravitational waves. In this case there was broad agreement on the basic theory and the type of instrument needed to detect the waves. Consequently it might be argued that the scientists were engaged in a standard attempt to replicate or refute each other's knowledge claims. Collins illustrates, however, that, in practice, the research process involved negotiation on how those knowledge claims could be assessed and there was considerable discussion '...... to establish what should count as a "working gravity wave detector".' (44).

These examples conform to Aspinall's generalised description of the development of new technology in which the first stage of development, which he calls 'infancy', involves intuitive and pioneering work including a search for settled principles of design. In the next, 'adolescent' stage:-

> The inventions best fitted to serve the most important uses survive, and definitive forms for accepted devices become extant. At some time during adolescence, the collection of inventions reaches the status of a body of knowledge, which becomes the basis for design. Design criteria and principles of good practice begin to emerge. (45)

Another example discussed by Mulkay is Wynne's study of Barkla's work on X-ray emissions (46). Initially this revolved around a particular low-intensity emission whch Barkla called the J-phenomenon. At first his ideas and experimental results were accepted by other physicists, but subsequently they were subject to increasing criticism as other experimental results contradicted them. Although Barkla revised his own theoretical position over time, he was still unwilling to accept the judgement of his peers and became increasingly isolated from the scientific community. What is significant about this case for the new sociology of science, is not whether Barkla's theory was 'correct', but that its rejection was not the consequence of an objective discussion of its theoretical validity or experimental results, as the scientific method requires. Instead it took the form of personal attacks and misrepresentations of his ideas together with the exercise of institutional power by withholding academic recognition and resources from anyone associating with him.

For the purpose of this chapter, the important aspect of the debate is Barkla's rejection of the accepted experimental technology and his consequent challenge to fundamental positivist principles. Many of the results which contradicted his own were obtained with an instrument called a spectrometer. Barkla argued, however, that the rays he was interested in were of such low intensity as to be unmeasurable by this instrument. He therefore continued to use an older, if less technically sophisticated method. Furthermore, he argued:-

> ...... heterogeneous X-ray beams do not always behave as a simple linear sum of individual wavelength components (a basic premise of orthodox spectrometer analysis), but rather as an 'organic whole'. (47)

As a result:-

> He continued to reject the use of the spectrometer and some of the scientific assumptions associated with that technique. He maintained that the fashionable research technology forced nature to fit preconceptions built into the design of the major instrument and that the discovery of fundamental results was sacrificed for highly precise routine measurements. (48)

It will be clear, therefore, how violently Barkla's ideas contradicted scientific orthodoxy and the mechanistic principles identified earlier in this chapter.

The sociological demonstration of the limitations of positivist/mechanistic principles rests, therefore, on the argument that scientists themselves do not apply the scientific method required by those principles. Instead, they are involved in a social process from which emerge agreed principles supported and maintained by social mechanisms including mores and sanctions. As a result, legitimacy based on the assumption of objectivity, and thus the claim of a special status for scientific knowlege, are not sustained in practice.

The Scientific Evidence

Sociological studies show that the research process of science does not conform to the positivist model. There is also evidence that the results of research cannot always be explained using the mechanistic model of nature. One of the most compelling examples of this phenomenon is provided by atomic physics. Scientists working in this field have been forced to recognise the explanatory limitations of Newton's mechanistic model of nature and in its place have adopted an alternative view in the form of the quantum and relativity theories. These represent nature as an inherently unstable and constantly changing whole whose relationships are intricately interwoven.

> Quantum theory thus reveals a basic oneness of the universe. It shows that we cannot decompose the world into independently existing smallest units. As we penetrate into matter, nature does not show us any isolated 'basic building blocks', but rather appears as a complicated web of relations between the various parts of the whole. These relations always include the observer in an essential way. (49)

Thus the Cartesian dualism of subject and object is transcended and, as Capra is concerned to point out, there are significant parallels between this new conception of nature and traditional mystical thinking.

> Quantum theory forces us to see the universe not as a collection of physical objects, but rather as a complicated web of relations between the various parts of a unified whole. This, however, is the way in which Eastern mystics have experienced the world, and some of them have expressed their experience in words which are almost identical with those used by atomic physicists ...... The idea of 'participation instead of observation' has been formulated in modern physics only recently, but it is an idea which is well known to any student of mysticism. (50)

Physics is not the only scientific sphere in which the mechanistic model is proving inadequate for expressing complex and abstract ideas. Mathematics too has begun to evolve new approaches, some of which question the adequacy of existing methods and representations for expressing some types of complexity. One area in which this has occurred is the field of catastrophe theory which is concerned with modelling situations where continuous causes have discontinuous and divergent effects. Such situations occur in the natural world when waves break on the shore-line, and in the social world when political unrest is translated into war. Commenting on the originator of catastrophe theory, Zeeman says:-

> Thom was forced to invent catastrophe theory in order to provide himself with a canvas large enough to display the diversity of his interests. Ever since the disappearance of natural philosophy from our universities and the fragmentation of mathematicians into pure and applied, our canvases have steadily been growing smaller and smaller. At least catastrophe theory marks a revival of natural philosophy, to be enjoyed once again for a while at any rate. (51)

Zeeman himself argues that:-

> Human behaviour is infinitely more complex and more mysterious and more delicately beautiful than could ever be explained by any analysis. (52)

Thom sees his work as beginning to question the assumption that knowledge must be presented mathematically; indeed he doubts whether this is possible in many cases.

> Thinking by numbers using statistics and computers is analysis, while thinking by pictures, drawing the graph and identifying the catastrophe, is synthesis. Synthesis is more important because it gives us concepts which we can grasp (or see) and upon which we can build further. (53)

Another area of mathematics exploring similar concepts is the theory of fractals. This begins from the apparently irrational concept of curves of infinite length where however fine the detail displayed, greater detail can always be revealed. The coastline is frequently cited as a natural example of this phenomenon. One application of this concept is the Mandelbrot set which represents the area in a two-dimensional plane defined by the behaviour of a simple function applied repeatedly to points on that plane. Durham (54) also describes the use of such ideas in a study of the occurrence of chaotic behaviour in continuous events. Modelling such events mathematically, he explains, can sometimes result in chaotic results simply from the use of discrete time steps. However in some cases, research suggests that any model will be unsatisfactory because the object of study is itself intrinsically unstable. One such example is a double pendulum which for certain energy values 'becomes skittish and seemingly unpredictable' (55).

Like Thom, researchers in the field of fractals find graphical representations of their ideas more appropriate than numerical ones. Durham reports one researcher's comment on using existing mathematical techniques:-

> "Very soon," said Peitgen, "we noticed that our intuition failed completely."

An attempt to get a feel for the problem involved some experiments in computer graphics. According to Peitgen:-

> "When we did this, our intuition really exploded." (56)

Hence Durham suggests:-

> They believe that their images, by boosting the power of human intuition, may lead to a better understanding of such varied phenomena as magnetism, weather and ecology.
>
> But their pictures also show how mathematical models can disintegrate into chaos. The message is that some phenomena may for ever lie beyond the reach of computation. (57)

The final outcome of this type of work is yet to be realised. Predictably it is meeting resistance from 'conventional' mathematicians and even its proponents are trying to locate it within the existing mathematical paradigm. However it does indicate once again that the limitations of positivist thinking are being experienced and recognised as such.

The Positivist Assumption of Sole Legitimacy

The evidence of sociology and scientific research, therefore, shows that the positivist and mechanistic models have limitations as a means for explaining both the research process and its results. In particular, the assumption of causality cannot deal adequately with abstract and complex relationships or which those involving discontinuity. A key factor in these limitations is the mechanistic concept of wholes. This view does not allow wholes to have characteristics not contributed by their constituent parts, and yet, the need for such a possibility has been indicated both by the abstract meanings given to technology discussed in the last chapter, and the evidence presented in this one.

In spite of these contradictions, it is necessary for positivism to assume that its principles provide the only valid form of 'scientific' argument and this has led it to demonstrate an antagonism to any other cognitive style. In Offe's words:-

> The social imagery of the achieving society is dominated by the abstract notion of 'efficiency'. This implies not only the repression of those *practical* desires which cannot demonstrate any functional contribution to the overall system of achievement, but also discrimination against any attempt to challenge the criteria of achievement and efficiency through the framework of concepts of use value. (58 - author's emphasis)

As Cotgrove (59) observes, criticisms of its dominant epistemological role are only aired by minorities.

Those criticisms which are made often counter positivism's claim to objectivity by emphasising the significance of social context in the development of knowledge. As well as being applied to science (60), this argument has been applied to subjects as diverse as art (61), mathematics (62) and education (63). One form of this argument suggests that the creation of knowledge does not follow a natural and preordained path but is directed by specific interests.

> Hence, the growth of knowledge should not be thought of as the result of random learning about reality, but as the correlate of the historical development of procedures, competences and techniques relevant in various degrees to the ends or objectives of cultures or sub-cultures. (64)

Once the notion of interest is introduced, there arises the possibility that knowledge will be distorted because it

> ...... is created, accepted or sustained by concealed, unacknowledged, illegitimate interests. (65)

This in turn raises the question of how the distortion of knowledge is to be recognised and which interests, if any, are legitimate.

One answer to this question has been to accept that any definition of legitimate interest must ultimately be based on value judgements (66). Others, however, continue to seek a neutral rationality. Lukacs (67) argues that capitalism (which we may see as one political implementation of positivist-industrialism) has been able to dominate industrial societies because it divides them into a number of independent spheres. As a result the laws of economics have been able to function as an autonomous body of pure, natural laws forming a closed system, and, at the same time, to inform all other aspects of society. The alternative he believes is grounded in historical materialism and he argues that:-

> ...... as far as *method* is concerned, historical materialism was an epoch-making achievement precisely because it was able to see that these apparently quite independent, hermetic and autonomous systems were really aspects of a comprehensive whole and that their apparent independence could be transcended.
>
> This semblance of independence, however, is no mere 'error' simply to be 'corrected' by historical materialism. It is rather the intellectual and conceptual expression of the objective social structure of capitalist society. To annul it and to transcend it means, therefore, to transcend capitalist society - in thought. (68 - author's emphasis)

Thus Lukacs sees no alternative to capitalism but its complete replacement. By 'in thought', he means that this should be achieved by the use of historical materialism to revitalise proletarian class consciousness. Habermas (69) has also sought to define a neutral rationality. He has developed a concept of systematically distorted communication through which, he argues, it is possible to identify the distortion in speech which results from the imposition of interest. Natural rationality therefore can be achieved by countering illegitimate interest and achieving undistorted communication.

The tendency of mechanistic thinking to divide knowledge into manageable parts is countered at both the theoretical and practical levels with the notion of 'totality' in which allowance is made for the possibility that the whole may have attributes which are not derived from the simple summation of its parts. At the theoretical level, Ellul applies this concept to technology when he argues that:-

> The technical phenomenon cannot be broken down in such a way as to retain the good and reject the bad. It has a "mass" which renders it monistic. (70)

Totality is also a key theoretical concept in dialectical thought (71) and for those who emphasise the structuralist aspect of Marx's work this is crystalised in his distinction between appearance and reality (72). At a more practical level, totality is found in the environmentalist arguments which maintain that the segmentation of knowledge leads to interference with the balance of nature without a full understanding of the implications of those actions. Furthermore, when unexpected consequences result, these are formulated into another 'problem' whose resolution requires a 'technological fix' by another group of experts. The result is a progression from one problem/crisis to another in an attempt to counteract the increasing imbalance. This, it is argued, is not a consequence of the specific type of technology used in each case but the nature of technology itself and its artificial division of knowledge (73).

Medicine is one particular area in which the role of interest and differentiation have been studied extensively, in part at least because it epitomises those concepts of professionalism and expertise which are fundamental to the cognitive style of modern industrial societies. Various studies have sought to demonstrate the social nature of the development of both the currently dominant institutional form of medicine and of its knowledge (74). Its view of the body as a complex machine, epitomised by medical specialisation and 'spare-part surgery', is contrasted with the alternative concern for totality and the related reluctance to interfere in natural systems which is to be found in homeopathy and Eastern medical practices. These treat each person as a unique mental/physical whole and treatment consists of stimulating the system's own resources to counter its ills and restore its natural balance. This involves different notions of 'problem' and wellness (efficiency) from the causal symptom/diagnosis/prognosis method of established Western medical practice. None the less, we can expect the latter to remain dominant, not least because it is now proving amenable to computerisation in the form of expert systems (75).

<u>The Status of Positivist Knowledge</u>

These criticisms of positivism do not necessarily undermine the value of the knowledge it has generated. The limitations of mechanistic models are well recognised by scientists and mathematicians (76). Hence those exploring atomic physics and fractals remain within the scientific community. The objects of their study lie at the extremes of knowledge and they would accept that in everyday life, the effects of, say, relativity are so small as to be insignificant. Consequently the mechanistic model provides an adequate basis on which to act in most circumstances. What their work does show, however, is that there are limitations to its possibilities. It is only a convenient means for ordering and explaining experience, not a definitive description of nature.

However this position does create two consequences for the knowledge generated by positivist methods. Firstly its validity cannot be considered unquestionable and secondly, it must be recognised that other practices may also provide 'valid' knowledge. Thus we are led to reassess present evaluations of existing knowledge. Illich (77), for example, argues that medicine has now gone too far in over-specialisation and intervention, to the extent that it is counter-productive resulting, for example, in new forms of treatment devised solely to counter the effects of others in the medical equivalent of the technological fix. Mulkay also suggests that some of the success used to legitimise the status of modern medical knowledge should be attributed to other causes. Thus he points out that most infectious diseases were already on the decline before the introduction of sulphapyridine although the latter is often considered to be a major contributing factor in that decline (78).

If positivist principles do not confirm the validity of knowledge, however, we are faced with the suggestion that all knowledge is relative and the consequent circularity when this argument is applied to itself. However, as Mulkay points out:-

> ...... when faced with the 'trap' of relativity, we can always choose to revise our conception of validity instead of abandoning a sociological approach to the creation of knowledge ...... [this] inclines more towards some form of hermeneutic analysis than the kind of causal analysis which traditionally gives this problem a misleading appearance of insolubility. (79)

In other words the problem of relativity is itself a consequence of positivism and becomes a non-problem if freed from that constraint. If the principles of positivism cannot supply the basis on which to develop a synthetic definition of technology, therefore, we need not be deterred from exploring other, non-positivist possibilities and this the next chapter will do.

SUMMARY

The purpose of this chapter has been to explore the possibility of constructing a synthetic concept of technology from positivist principles. The nature of those principles, in the form of the mechanistic model, were identified and shown to create the mutually supporting set of ideas on which the commonsense concept of technology is typically based. The key principle in this concept, it was suggested, was a view of the nature of wholes whereby any object can be reduced to its basic elements and reconstructed without any change to its composition. Arising on this foundation are specific ideas of complexity and ways of dealing with it, together with particular notions of problem and efficiency, and hence of rationality and the function of quantification. These ideas are bound together by the assumption of objectivity which legitimises the argument that together they represent the one valid means of obtaining 'scientific' knowledge, that is knowledge unbiased by subjective interpretation. As a result positivism is antagonistic to any alternative epistemological position.

However, the possibilities offered by positivist models were shown to be limited by these principles. The sociology of knowledge shows that scientific research itself is not conducted according to those principles whilst the results of research in physics and mathematics both show that the mechanistic mode of expressing ideas is inadequate for explaining nature as it is now being experienced. These new concepts are more akin to modes of thinking which emphasise the totality of nature, the complex and constantly changing relationships of its constituents, and the inadequacy of concrete concepts. The conclusions of this argument were not found to invalidate existing knowledge. Rather they redefined it as the consequence of a pragmatic process of negotiation during which working principles and hypotheses are agreed. The status of this 'knowledge' is the same as any resulting from a social process and consequent on the cultural resources available to that process. However the principles of positivism do not themselves allow for this interpretation. If positivism can neither encompass these ideas, nor accept the need to adopt alternatives to its own epistemology, then we must conclude that it cannot form the basis for the synthetic concept of technology being sought and in the next chapter the possibility of a definition based on non-positivist principles will be explored.

NOTES FOR CHAPTER 3

1. Berger P. et al 'The Homeless Mind', 1973, Random House, New York

2. see for example De Millo R.A. et al. 'Social Processes and Proofs of Theorems and Programs' in *Communications of the Association of Computing Machinery* May 1979

3. Mowshowitz A. 'The Conquest of Will', 1976, Addison-Wesley, Reading Mass., p. ix

4. Pollard S. 'The Genesis of Modern Management', 1968, Penguin, Harmondsworth

5. Mowshowitz A. 1976 op cit. pp. 229-230

6. Kuhn T.S. 'The Structure of Scientific Revolutions', 1970, Chicago University Press, Chicago

7. see Bohme G. et al. 'Finalization in Science' in *Social Science Information* No.15, 1976

8. see Jenkins C. and Sherman B. 'The Collapse of Work', 1979, Menthuen, London

9. Babbage C. 'On the Economy of Machinery and Manufactures', 1835, Charles Knight, London

10. Ibid. p. 12

11. Sklair L. 'Organised Knowledge', 1973, Paladin, St. Albans, pp. 242-3

12. Giddens A. 'Capitalism and Modern Social Theory', 1971, Cambridge University Press, London, p. 179

13. Boudon R. 'The Logic of Sociological Explanation', 1974, Penguin, Harmondsworth, p. 11

14. This is discussed in Mulkay M.J. 'Knowledge and Utility: Implications for the Sociology of Knowledge' in *Social Studies of Science* Vol. 9, 1979

15. see for example Goldman P. and Van Houten D.R. 'Managerial Strategies and the Worker: A Marxist Analysis of Bureaucracy' in Benson J.K. (Ed.) 'Organisational Analysis', Sage, Beverley Hills, p. 110

16. see Pfeffer J. 'Organisational Design', 1978, AHM, Arlington Heights Ill.

17. on the latter see Noble D.F. 'America by Design', 1977, Knopf, New York

18. Winner L. 'Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought', 1977, MIT Press, Cambridge Mass, p. 242

19. Merton R.K. Forward to Ellul J. 'The Technological Society', 1965, Jonathan Cape, London, p. x

20. see Chapter 7

21. Winner L. 1977 op cit.

22. The various theoretical positions in positivism are discussed in Kolakowski L. 'Positivist Philosophy', 1972, Penguin, Harmondsworth.

    As we shall see in the discussion below, the limitations of positivism stem from its reductionism. The identification of these different principles therefore must be seen as a means of describing the mechanistic model, and we must be aware of the possibility that it encompasses characteristics which are more than the sum of these parts.

23. Layton E. 'Technology as Knowledge' in *Technology and Culture* Vol. 15/1, Jan. 1974

24. see also Cardwell D.S.L. 'Technology, Science and History', 1972, Heinemann, London

25. see Burtt E.A. 'The Methodological Foundations of Modern Physical Science', 1932, Routledge & Kegan Paul, London, p. 301

26. for example Ellul J. 'The Technological Society', 1965, Jonathan Cape, London; Heidegger M. 'The Question Concerning Technology' in 'Krell D.F. (Ed.) 'Martin Heidegger: Basic Writings', 1978, Routledge & Kegan Paul, London

27. One example of accelerated development is the computer, see chapter 5

28. Lipscombe J. and Williams B. 'Are Science and Technology Neutral?', 1979, Butterworths, London

29. Ziman J.M. 'Teaching and Learning about Science and Society', 1980, Cambridge University Press, Cambridge

30. for a summary of Taylor's work see Pugh D.S. et al. 'Writers on Organisations', 1971, Penguin, Harmondsworth

31. Rose M.J. 'Industrial Behaviour - Theoretical Developments since Taylor', 1975, Allen Lane, London

32. Habermas J. 'Legitimation Crisis', 1976, Heinemann, London

33. see Burtt E.A. 1932 op cit.

34. Lipscombe J. and Williams B. op cit., p. 6

35. Berger P. et al 1973 op cit.

36. This is similar to the position adopted by Habermas which is discussed in the next chapter

37. Mulkay M.J. 'Science and the Sociology of Knowledge', 1979, George Allen & Unwin, London.

    The work of Mulkay is taken here as typifying recent developments in sociology of science. Other contributors include Barnes, Wynne, Pinch and Woolgar whose work is referred to elsewhere.

38. Mulkay M.J. 'Knowledge and Utility' 1979 op cit., p. 64

39. Ibid. p. 65

40. Mulkay M.J. 'Science and the Sociology of Knowledge' 1979 op cit., pp. 60 & 61

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CHAPTER 4

THE NON-POSITIVIST ALTERNATIVE

CONSTRUCTING A SYNTHETIC CONCEPT

In the last chapter it was argued that positivism cannot provide an adequate basis for reconceptualising technology in a way which synthesises its concrete and abstract aspects. This chapter explores an alternative basis for such a concept by drawing on the non-positivist ideas of various social theorists. The object is to identify those elements which can be incorporated into the new concept, to highlight questions which it must answer and to identify potential difficulties in its construction. As in chapter 2, there is no attempt to provide a full statement or critique of each author's work, only to draw on their discussions where it is immediately useful in developing the current project.

The argument will be developed in three stages. Firstly the possibility and basis of a synthetic concept will be identified in the work of Marx. In itself, however, this will not prove sufficient, and the second stage will explore a number ways of overcoming its limitations. Finally the the various ideas and principles explored in the first two stages will be brought together to construct the new concept of technology.

MARX - CONTRADICTION IN A DUAL RELATIONSHIP

The Beginnings of a Synthesis

The starting point for this reconceptualisation of technology is the work of Marx. In itself this will not be sufficient, but in seeking to provide a radical critique of his own society, Marx began to face the issues and develop a methodology which provides a firm basis for the project. There are many interpretations of Marx's work, each pursuing its author's ends and providing, or implying, a definition of 'technology'. The interpretation offered by Gendron (1) was discussed in chapter 2. This provides a superficial and popularist reading of Marx reflecting the positivist mode of thought rather than Marx's own critical method. In the works of Lukacs (2) and the Frankfurt School (3) another interpretation emphasises the subjective alienation resulting from capitalist and technological societies. By contrast, Althusser (4) asserts an objective and materialist reading of Marx. The interpretation used here does not draw directly on any of these authors but describes a reading of Marx undertaken with the specific project of this thesis in mind.

To identify Marx's potential contribution to a definition of technology, we must begin, as he does, with the nature of work and his statement that:-

> We presuppose labour in a form in which it is an exclusively human characteristic ...... At the end of every labour process, a result emerges which had already been conceived by the worker at the beginning ...... The use and construction of instruments of labour, although present in the germ among certain species of animals, is characteristic of the specifically human labour process ...... It is not what is made but how, and by what instruments of labour, that distinguishes different economic epochs. Instruments of labour not only supply a standard of the degree of development which human labour has attained, but they also indicate the social relations within which men work. (5)

We find here that the way people work, and the instruments they use, make them unique in the natural world. They also indicate the form of social relations and provide a measure of development or, what is taken to be its equivalent, the extent of human control over nature. This statement does not mean that Marx is a technological determinist, rather it indicates his awareness of the interrelated character of societies whereby their various institutions must change in sympathy with each other. The economic epochs which he defines are used to demonstrate his argument that such changes come about in a process involving two key moments. On the one hand, particular forces of production are necessary for certain types of social development, whilst on the other hand, a particular type of society is necessary to create the conditions and the need for those forces of production.
Thus change arises from a dual motion whereby each moment creates possibilities and sets limits on the other. Within each epoch a point is reached where further accommodation of the contradictions between them becomes impossible and a revolutionary transformation occurs heralding a new epoch. In Marx's own words:-

> At a certain stage of their development, the material productive forces of society come in conflict with the existing relations of production, or - what is but a legal expression for the same thing - with the property relations within which they have been at work hitherto. From forms of development of the productive forces these relations turn into their fetters ...... No social order ever perishes before all the productive forces for which there is room in it have developed; and new, higher relations of production never appear before the material conditions of their existence have matured in the womb of the old society itself. (6)

For Marx, the social forms of production have three basic elements:-

a) Labour Power - the application of the worker's skill and strength,

b) Nature - the object of labour,

c) Instruments of Labour, ie:-

> ...... a thing, or a complex of things, which the worker interposes between himself and the object of his labour and which serves as a conductor, directing his activity onto that object. He makes use of the mechanical, physical and chemical properties of some substances in order to set them to work on other substances as instruments of his power, and in accordance with his purposes. (7)

Once again Marx makes clear the nature of this process:-

> The labour process, as we have just presented it in its simple and abstract elements, is purposeful activity aimed at the production of use-values. It is an appropriation of what exists in nature for the requirements of man. It is the universal condition for the metabolic interaction between man and nature, the everlasting nature-imposed condition of human existence, and it is therefore independent of every form of that existence,

> or rather it is common to all forms of society in which human beings live. (8)

Hence Marx does not isolate the instruments of labour but discusses them as an integral part of the essentially human and social process of labour. They have no meaning outside that process and yet are a necessary part of it.

Although he talks about people using nature to achieve their own ends, he recognises a reciprocal dependence in this relationship.

> Labour is, first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature. He confronts the materials of nature as a force of nature. He sets in motion the natural forces which belong to his own body, his arms, legs, head and hands, in order to appropriate the materials of nature in a form adapted to his own needs. Through this movement he acts upon external nature and changes it, and in this way he simultaneously changes his own nature. (9)

Marx distinguishes people from other animals by their capacity to act on, rather than react to, the environment. They distance themselves from it by manipulating it symbolically to conceptualise future states. The essence of technology in this situation is to make concrete the interface between humans and their natural environment allowing the extension of human abilities by the use of tools and the creation of social organisations. Consequently, it provides a potent focus for studying both the content and discontinuities between different epochs:-

> Technology reveals the active relation of man to nature, the direct process of the production of his life, and thereby it also

> lays bare the process of the production of the social relations of his life, and of the mental conditions that flow from those relations. (10)

<u>The Evolution of Capitalism as a Case Study</u>Although Marx distinguishes analytically between the forces and relations of production, he also makes clear how closely they are related in practice. The nature of this relationship is demonstrated empirically in his description of the evolution of capitalism. This process required the gradual laying down of the foundations of capitalism within an essentially feudal society until transformation to the new form became inevitable. This occurred when the economic basis of the old society, domestic industry and self-sufficiency agriculture, were unable to meet the increasing demands of urban markets at home and foreign trade created by colonial expansion abroad.

Marx labelled the first stage of the establishment of capitalism 'manufacture'. This began with employers concentrating a number of craftsmen under one roof, each making an entire article or those parts of one for which their craft suited them. At this stage it is possible to identify the emergent capitalist relations of production with the selling of labour and the making of commodities, but the instruments and division of labour are largely unchanged. However change in these areas was to follow. In particular, the work of each craftsman became more specialised and the tools they used became more specialised. Hence Marx comments:-

> But as soon as the different operations of a labour process are disconnected from each other, and each partial operation acquires in the hands of the worker a suitable form peculiar to it, alterations become necessary in the tools which previously served more than one purpose. The direction taken by this change of form is determined by the particular difficulties put in the worker's way by the unchanged form of the old tool. Manufacture is characterized by the differentiation of the instruments of labour - a differentiation whereby tools of a given sort acquire fixed shapes, adapted to each particular application - and by the specialization of these instruments, which allows full play to each special tool only in the hands of a specific kind of worker. (11)

With the break-up of production into specialised tasks, the capitalist was able to combine these tasks in new ways to take advantage of the varying degrees and kinds of skill required and the speed possible for each. These advantages were spelt out, among others, by Adam Smith and Charles Babbage both of whom are quoted by Marx in his discussion. Thus he concludes:

> By dissection of handicraft activity into its separate components, by specialization of the instruments of labour, by the formation of specialized workers and by grouping and combining the latter into a single mechanism, the division of labour in manufacture provides the social process of production with a qualitative articulation and a quantitative proportionality. It thereby creates a definite organisation of social labour and at the same time develops new, and social, productive powers of labour. (12)

The link between the forces and relations of production is therefore provided by their organisation into a definite structure which becomes part of the forces of production and embodies the relations of production in the form of the division of labour and the wage labour market.

But Manufacture, even at its most developed, was only one stage towards a fully capitalist economy. The possibilities of specialisation within an essentially craft-based system were still unable to meet the growing demands for production. Thus further developments resulted both from the contradictions being experienced and from the momentum of change already set in motion.

> At a certain stage of its development, the narrow technical basis on which manufacture rested came into contradiction with requirements of production which it had itself created ...... When the system had attained a certain degree of development, it had to overthrow this ready-made foundation [of handicraft], which had meanwhile undergone further development in its old form, and create for itself a new basis appropriate to its own mode of production ...... large-scale industry also came into conflict with the technical basis provided for it by handicrafts and manufacture. (13)

The 'certain stage' of development occurred when production could no longer be increased by further development of the tools available or exploitation of the labour force which had reached the limits of its strength and skill. In Britain this point was hastened by legislation limiting the hours of work and types of employment allowed for women and children. Hence a new source of labour power had to be found and manufacture was replaced by fully developed capitalism which 'makes science a potentiality for production which is distinct from labour and presses it into the service of capital' (14). This definition is quoted by Marx from W. Thompson who also noted that knowledge, which was once the attribute of the workman, was now being used to dominate him (15).

The distinction between Manufacture and capitalism is emphasised by Marx's discussion of the formal subsumption of labour under capital (16). Whilst there is a generalised capitalist relationship in Manufacture in the sense that one party provides the finance and another the labour power, it takes the specific form found in capitalism when it leads to 'a fundamental modification in the real nature of the labour process, the actual process of production.' (17). This only becomes possible when a certain scale of production is achieved which enables the capitalist to derive 'relative surplus-value'.

> With the production of relative surplus-value the entire real form of production is altered and a *specifically capitalist form of production* comes into being (at the technological level too). Based on this, and simultaneously with it, the corresponding *relations of production* between the various agents of production and above all between the capitalist and the wage-labourer, come into being for the first time. (18 - author's emphasis)

It is clear that technological change is a central feature in this transformation:-

> But on this foundation there now arises a technologically and otherwise *specific mode of production* - capitalist production - which transforms the nature *of the labour process and its actual conditions.* (19 - author's emphasis)

However change is not technologically led, rather Marx is emphasising that the change is from one total form of social organisation to another and can only be complete when the nature of the labour process and the technology it uses are in harmony with the emerging institutions of the new society. Marx saw machinery as one factor in the development of the forces of production but not as their defining element.

> The machine, therefore, is a mechanism that, after being set in motion, performs with its tools the same operations the worker formerly did with similar tools. (20)

Marx distinguishes between humans as natural users of tools and the use of tools/machines in capitalism. The latter represents an unnatural division of labour and distortion of human relations. Thus he says:-

> Owing to the extensive use of machinery and to division of labour, the work of the proletarians has lost all individual character, and, consequently, all charm for the workman. (21)

He acknowledges none-the-less the value of mechanisation in providing for the necessities of life. His critique arises from the form it takes in capitalist society.

> It is sometimes said about machinery, therefore, that it *saves labour;* however, as Lauderdale correctly remarked, the mere *saving* of labour is not the characteristic thing; for, with the help of machinery, human labour performs actions and creates things which without it would be absolutely impossible of accomplishment. The latter concerns the use value of machinery. What is characteristic is the *saving* of necessary labour and the creating of *surplus labour.* (22 - author's emphasis)

Marx does identify an objective element in production in the form of 'use value' but this recognises the complex dependency of people on nature rather than the simple neutrality of technology approach adopted by Gendron. Mechanisation may create enormous productive capacity but Marx's philosophy of history insists that it must undergo a revolutionary transition to be appropriate to a post-capitalist society. Clearly Marx believes that an increasingly 'scientific' understanding of nature can provide the technical ability to end physical want. This may explain his ambivalence towards the form taken by capitalist technology which both enslaves the workers and offers the possibility of freedom from want.

The Contribution of Marx

What Marx contributes to the reconceptualisation of technology, therefore, is a description of its role within society, in particular in social change. Because technology is not an isolated concept for Marx, we do not find it discussed in the same terms as the uses of 'technology' described in chapter 2, nor does it fit comfortably into the continuum used to locate them. Instead it offers a view of an integrated society in which technology is one element, an interface between the concrete object of labour and the abstract relations in which it takes place. Because Marx sees labour as the defining feature of society, technology necessarily shares in the social relations in which labour occurs and must change as they do. Thus Marx provides the beginnings of a synthesis which embraces the significance of technology for the symbolic actions and subjective meanings of individuals, on the one hand, and for concrete action on the other.

A number of key ideas will be adopted from this description of Marx's position for use in the reconceptualisation of technology. These will provide the substantial basis for understanding technological change and centre on Marx's recognition of the dual relationship through which that change occurs. This replaces a simplistic cause and effect explanation with a device for understanding the complexity of change within an integrated whole. Within that framework, the occurence of change will be explained by two moments; the accumulation of contradictions in praxis and autonomous development within the logic of existing structures, either through the momentum they generate or their own internal contradictions. This recognises the ultimate discontinuity of epochs when fundamental institutional logic changes but allows for that logic to respond to change and delay breakdown until all its resources for adjustment are exhausted.

THE LIMITATIONS IN MARX

The Residue of Positivism

Important as this contribution is, Marx's position is not a totally satisfactory basis for the new concept of technology. A key to this inadequacy is Marx's concentration on the economy of a society as a basis for explaining all its other features. Although his analysis of capitalist relations uncovers the structure of domination in the economic relations of capitalism, it has proved less useful in explaining other forms of domination which have become central concerns since his time. In Poster's words:-

> By totalizing the social field in terms of the universal suffrage of wage labour, Marx at the same time effected a closure which prevents other modes of domination from being named and analyzed. (23)

Similarly, whilst Marx acknowledges the mental and symbolic elements of the technological interface, his discussion of capitalism emphasises its concrete aspect in the form of machines. Because of this it is not immediately applicable to modern industrial societies where symbolic knowledge and information constitute a growing part of applied technology. Thus, although he recognised the duality of the relationship between people and nature, Marx still retains vestiges of positivism whereby he conceives of people dominating nature to meet their own needs and consequently represents development as progress towards control through a series of necessary stages.

We must recognise that Marx is discussing the capitalism of his own time in which the concrete benefits of science-based industry were the most apparent consequence of industrialisation. He recognised some of the newly developing features such as limited liability companies, but did not analyse them fully. We must also be aware of the political project to which he applied his work in which the experience of domination most visible and politically exploitable was the uneven distribution of the benefits of the products of labour. Thus his revolutionary concepts, which can now be seen to imply the redefinition of the positivist dichotomies, were constrained in his own writing within the terminology of positivism resulting in the creation of the new base/superstructure dichotomy and a new basis for a progressive description of history. According to Poster:-

> Marx accomplished the task of critical social theory perhaps to a degree never equalled before or since by demonstrating the historicity and specifying the mechanisms of domination inherent in industrial capitalism. However, he fell back into the ideological mode of liberal political economy by framing the advances of his position in terms of liberal norms, i.e., universal emancipation. After revealing the inability of liberal political revolution to achieve democracy (classless society), he went on to argue that the proletarian social revolution could accomplish that end. The metaphysic of the complete abolition of domination reinserted itself within critical theory. (24)

As a result, it has been easy for writers like Gendron (25) to retain the positivist dichotomies and to avoid exploring the difficult terrain of the pragmatic structure towards which historical materialism leads. Similarly, because Marx's political concerns led him to idealise the process of labour and posit an apparently utopian, if ill-defined, view of communist society as the social vision which could offer hope in the industrial conditions of nineteenth century capitalism, others have limited their vision to one of revolutionary development through proletarian revolution.

In practice Marx seems to have been torn between the logic of his own method and a concept of change which demanded that the material benefits of capitalist machinery be retained in the next stage of development. This contradiction has been borne out in Eastern Europe where the political system has changed but the technological basis for society has not and where the relations embedded in the latter do not allow the transition which Marx envisaged. It would be wrong, therefore, to read into Marx's work the issues and values of the 1980's and to attempt to identify any specific ecological stance or significant critique of the mechanistic way of thinking. To apply his work to contemporary issues we must identify in his arguments those elements which are of enduring value and these are to be found in his method rather than in his empirical findings. The need for such an approach is demonstrated by the weakness of social criticism which fails to do so.

Sumner

Sumner's attempt to identify the ideological content of writing provides an example of such failure (26). He defines ideology as:-

> ...... elements of consciousness generated within and integral to social practice, reflecting the structure of such practice, and the appearance of the practical context. (27)

As such it is:-

> ...... integral to every social practice and thus acts as the cement which prevents an unstable social structure from falling apart. (28)

He guards against the suggestion that ideology has an independent existence, rather it is a 'sign of something other than itself' (29), although it may find concrete expression 'embodied within the material products of social practice' (30).

He discusses a number of methods of textual analysis including content analysis, structuralism, semiology and the work of Althusser and concludes that:-

> Taking them as a whole, their general defect is that they assume more about the meaning of the words of the text (or, meaning of the significant units) than they explicitly discover. (31)

In other words the analysts impose their own ideas on the text rather than objectively extracting its author's meaning. As a result Sumner proposes an alternative approach based on historical materialism. Hence he argues that:-

> All ideologies originate within social practices and, once formed, are integral to their operation and development. Ideologies can also be operative within social practices other than their necessitating practices. They may act in the structuring of new practices. Some practices tolerate or use ideologies developed elsewhere. Origination, tolerance, use, maintenance and structuring capacity are all possibilities which must be distinguished and examined for their function in social formation. (32)

This statement appears to contain the essentials of the interpretation of Marx being offered in this chapter. However Sumner's definition of social formation immediately constrains him within Marx's own limitations:-

> A social formation is a totality of social practices interconnected in a variety of ways and fundamentally circumscribed, ranked and influenced by the structures of economic (social) practice. (33)

The method of textual analysis which he derives from this position is detailed and thorough but his work is undermined by his failure to recognise his own ideological assumptions. Historical materialism is not ideological, he argues, because any society based on its principles would not be unstable and therefore would not need the 'cement' of ideology. In this he holds the same idealistic view of historical materialism as Lukacs and by dint of definition and assertion he deflects from himself the criticism he levels at others. Hence his method of reading becomes not so much a search for understanding but the confirmation of his basic assumption.

Althusser

Although Althusser's (34) work is rejected by Sumner, it also retains Marx's focus on economic production. In this case the object is to counter what Althusser sees as invalid humanist interpretations of Marx, typified by Lukacs, and to reassert the scientific marxism of 'Capital'. Marx's theoretical position, according to Althusser, underwent a transformation in which his early ideas were superseded by those in his later work which must therefore be taken as the only correct representation of his fully developed theory.

In his statement of Marx's position, Althusser tries to account for the experience of capitalist and socialist societies since Marx's time. Hence he argues that Marx did not rely on a single basis of explanation, indeed he suggests that it was this very point which Marx rejected in Hegel. Rather, following Engels, Marx recognised three fundamental social entities, economy, ideology and politics. Each can be both determining and determined, and may, at any particular time, be the dominant aspect of a social formation and hence the source of contradictions which bring about social change. Even so, Althusser maintains that the economy is still the determining factor in the last resort.

We may see Althusser's theoretical manoeuverings as an attempt to make a marxist explanation more relevant to modern capitalism where domination and conflict are visible in a broader range of issues than the economic. At the same time he is trying to preserve Marx's original analysis and to reserve a special place for science and theory whereby they rise above social and historical limitations to express universal truths in the form of historical materialism. However he does not ground his theory in the material world of human practice, and as a result, in the assessment of Geras (35), he reverts to an idealist position. He also fails to overcome the limitations on understanding which result from an assumption of economic domination as the essential object of social critique.

Habermas

If both Sumner and Althusser fail to overcome the limitations which stop Marx's methodology fulfilling its potential for breaking the bounds of positivism, we must look elsewhere. One possibility is the work of Habermas who specifically identified a need to 'update' Marx. The alternative which he offers escapes Marx's emphasis on economic production by adopting a philosophy of history the main theme of which is the progressive development of human knowledge. The search for knowledge, Habermas argues, is directed by 'invariant' interests which 'determine the aspect under which reality can be objectified and thus made accessible to experience in the first place.' (36). Three interests are identified; technical, practical and emancipatory; corresponding to the social spheres of work, interaction and domination respectively. Each is subject to a particular mode of scientific investigation; analytical, hermeneutic and critical. The technical and practical interests are concerned with control of the natural and social environments whilst the emancipatory interest defines the objective, ideal state, towards which both should be directed. Habermas has found the idea of emancipatory interest difficult to sustain in his later work and it has tended to merge with the practical interest.

His work begins with the contrasting attributes of the practical and technical spheres of interest (37). This division has a long history (38) starting with the division between natural and moral philosophy in Ancient Greece through to the work of Kant and Hume. For Habermas the technical interest is concerned with the world of work and consists of means-ends relationships adopted in the resolution of 'problems' for which it provides an unambiguous definition of success and failure. The practical interest concerns the moral aspect of society and the development of social institutions and relations. Its is expressed through the development of reciprocal relationships in the process of maintaining social intercourse and thus it has a negotiated meaning of success and failure.

Therborn summarises the distinction as:-

> In labour, man confronts nature in instrumental action; in interaction, he confronts society in normative behaviour. (39)

Although Habermas offers variations on these descriptions in his later work, the basic distinction remains:-

> Whereas the rationalization of purposive-rational action depends on the accumulation of true (empirically or analytically true) knowledge, the rationalizable aspect of communicative action has nothing to do with propositional truth; but it has everything to do with the truthfulness of intentional expressions and with the rightness of norms. (40)

The programme which has emerged from this philosophy has concentrated on three areas (41):-

a) a general theory of communication,
b) a general theory of socialization,
c) a reconstruction of historical materialism.

The first two fall within the practical sphere of interest and Habermas justifies his concentration in this area, as opposed to the focus in Marx's work on the technical interest, by his proposals for the reconstruction of historical materialism. The latter is undertaken on the grounds that modern capitalism is significantly different from that in Marx's own time, and in particular that:-

a) the state now plays a major role in the economic domain,
b) science/technology has become a major source of surplus value in its own right,
c) there is a greater degree of economic concentration.

Habermas's version of historical materialism entails a process of development through qualitatively different stages of learning, each advance involving more abstract and universal thought than the previous one. These stages, which owe a great deal to Piaget, are applied equally, albeit with differences of detail, to the development of individuals and societies. Although development is neither necessary nor uni-directional, each stage defines the limits of knowledge for the next and hence the possibility of technical development. Habermas argues that:-

> The endogenous growth of knowledge is thus a necessary condition of social evolution. But only when a new institutional framework has emerged can the as-yet unresolved systems problems be treated with the help of the accumulated cognitive potential; from this there *results* an increase in productive forces. (42 - author's empahasis)

Although work and interaction are subject to the same philosophy of history in this scheme, Habermas argues that each develops separately and not in tandem as described by Marx in 'Capital'. Whilst the latter puts the forces and relations of production at the base of society with a superstructure of social institutions, Habermas treats them as parallel but distinct modes of social development.

Habermas's position diverges from that of Marx, therefore, by relocating to the sphere of interaction the explanation of social crisis and the potential for resolving social injustice. The potential for crisis in modern capitalism, he argues, is not in the technical sphere of production but in the political sphere, especially in the ability of the state to retain its legitimation within society (43). Marx's later work, according to Habermas, lost the early humanist insights related to the practical interest and led to the very situation which Habermas criticizes in modern capitalism, the confusion of the technical and practical interests leading to the inappropriate application of purposive-rational thought. Habermas therefore specifically rejects the synthesising potential in Marx.

The focus of his own critique of modern capitalism is a general theory of communication in which he argues that the state's legitimization of its position by an appeal to technical competence would not withstand examination in undistorted discourse. As it is, he suggests, increasing difficulty is being experienced in maintaining the claim to legitimacy in the face of continuing social and economic dislocations. The revolutionary potential of this situation lies in repoliticising the public to become directly involved in decisions affecting them rather than accepting spurious claims to technical competence on subjects which can only be dealt with by negotiation.

In his emphasis on the humanist element of Marx's work, Habermas is following the tradition of the Frankfurt School which questions the inevitability of critical and revolutionary consciousness arising out of engagement in labour in the way Marx suggests. Change, it is accepted, must come through practical engagement in society (44), however, because the basis of critique is idealistic rather than materialistic, the lead is to be given not by workers whose practical engagement is their labour, but by intellectuals. The outcome of Habermas's work therefore is an inversion of the leading edge of historical materialism and a reversion to the idealism of Hegel and Kant.

This position, as McCarthy (45) notes, has led Habermas a long way from his declared methodology and, in spite of his own insistence that theory must be grounded in practice, his position has become increasingly abstract without any real grounding in, or specific prescription for, practice. However McCarthy's comment only hints at the fundamental weakness of the direction which Habermas has taken in losing the grounding of material practice. The importance of this as a basis for theory is discussed by Marx and Engels in 'The German Ideology' (46). In Larrain's words:-

> It is by means of the concept of practice that Marx tries to solve the problem of the relation between consciousness and reality. (47)

For Marx, practice is not simply a question of social interaction; people act in, and change, both the natural and social aspects of their world, creating in the process structures which are the starting point for future action. In this context 'Capital', through its description of the economic institution of capitalism, can be interpreted as a study of one particular kind of practice, of the social structures which result, the objective and historical imperatives and constraints on action which are created, and the resulting forms of domination and conflict. The breakthrough which Marx achieves as a materialist is to reject those forms of materialism which see reality only as an object, and to frame the social and natural aspects of the environment in one set of relations. The consciousness and practice of individuals has the effect of socialising nature and the relationship between nature and society is fundamentally reformulated.

The approach adopted by Habermas recreates, through the work/interaction duality, the distinction between nature and society. In re-asserting this division without ever demonstrating its viability, Habermas loses the understanding to be found in

Marx whereby the means of production and the relations of production form an integrated basis for action. Habermas strips work of its social element, leaving it to a separate, objective existence with its own history, different from the history of the relations between people. In effect he reverts to the idealism which gives a special status to scientific knowledge and in which the mark of human development is the state of its knowledge. It was this view which had led Marx to comment that:-

> Hence it happened that the *active* side, in contradistinction to materialism, was developed by idealism - but only abstractly, since, of course, idealism does not know real, sensuous activity as such. (48 - author's emphasis)

The practical result of his divergence from the dual relationship described by Marx is that Habermas locates the potential for a non-alienating society in the reconstitution of social relations independent of, or at least in advance of, any change in the material mode of existence. Knowledge becomes the precursor of change and new technology can only develop if the appropriate knowledge potential is already available. He justifies the label of historical materialism for this theory by arguing that the stages of development are the statics of a process whose dynamics are the need to respond to environmental pressures using the knowledge available to do so. Thus he argues that:-

> ...... the change of normative structures remains dependent on evolutionary challenges posed by unresolved, economically conditioned, systems problems and on learning processes that are a response to them. (49)

However the dynamics of this arrangement cannot provide the stimulus for change found in Marx's model of contradiction and autonomous momentum. Instead Habermas is obliged to rely on the assumed natural progression of a single element of the social formation, knowledge.

His project I would argue, is fundamentally correct in that he is seeking to account for the changes in capitalist society since Marx's time and to broaden the practice of critique to embrace the non-economic aspects of society. The three interests which he identifies suggest analytically useful categories which in the concept of technology constructed later in this chapter are broadly translated into three levels of analysis; concrete, institutional and social. The latter is used to explain the fundamental cohesion of the institutions which make up the social whole, the role which Habermas is unable to sustain for his notion of emancipatory interest because of the sharp distinction he makes between the technical and practical interests.

Thus what Habermas demonstrates are some potential pitfalls of attempting to modernise Marx's position without retaining its essential integrity. He also identifies two issues which a new definition of technology must address. The first concerns whether technology, or the knowledge which it uses, precedes the emergence of a need or arises out of that need. The second question concerns the identification of a group or groups which will represent the active element of social change. Whereas Habermas is obliged by the logic of his argument to give definitive answers to these questions, I will argue that a concept which synthesises the concrete and abstract elements of technology and emphasises the pragmatic nature of technological change, the answer to each may be different in different social circumstances.

DEVELOPING THE INSIGHTS OF MARX

Sartre

Like Habermas, Jean-Paul Sartre looks to Marx for the basic grounding of his theoretical position. However Sartre's ideas have been developed within the context of existentialist philosophy and the political arena of contemporary France (50). The focus of his social analysis is human action, and, for him, all social facts are ultimately reducible to the actions which initiated them. Thus Sartre recognises only two ontological categories, objects which exist regardless of human existence and those arising from human action in the world, that is '...... the world as it may be in itself and as it is structured through our interventions as engaged beings ......' (51).

In the process of structuring, which translates action into social facts, Sartre recognises an element of pre-structuring arising from the predilection of people to see the world in a specifically human way. However this provides only a coarse filter of experience and is subject to the much more demanding selectivity of engagement. For Sartre, 'engagement' represents the purpose of individuals in taking action and is seen as the normal mode of historical existence. Through engagement individuals are constantly totalising their world so that, like Piaget, Sartre has a pragmatic concept of existence as a perpetual balancing act, but without the former's connotations of progress and development.

This constant totalising activity does not mean that concrete totalities do not exist, and Sartre uses the term 'practico-inert' to represent the objective results of action (52). However the totalising activity which creates them continues afterwards and the practico-inert then becomes a constraint on its creators who must seek a new totalisation to negate it. One example of the practico-inert, which is discussed at length by Sartre, is that of the 'group'. Groups arise initially from the common project of a number of people. However, Sartre sees such conjunctures as inherently unstable and temporary so that to become established groups develop a hierarchy and leadership. As a consequence the individual members must subordinate their own projects to membership of the group which therefore becomes a form of domination. Desan summarises this relationship as follows:-

> ...... the objectification of [man's] *praxis* may escape him and constitute a passive and inert totality which turns around to negate him ...... There is a perpetual circularity between *praxis* and practico-inert, between the constitution of a group and its dissolution back into a series. (53 - author's emphasis)

Because the group becomes practico-inert and hence a constraint on its members, Sartre does not see social class, one particular type of group, as an adequate basis for mutual action. Hence, in discussing the colonial system, he argues that it:-

> ...... did indeed respond to the objective needs of French capitalists generally, but nevertheless it was originally built by *particular* interests ...... The colonial struggle is not an unavoidable evolution of molecular forces ...... colonialism was originally built by living men ...... (54 - author's emphasis)

Nor can the children of the original colonialists escape responsibility for the continued existence of the system which must 'still be maintained and reinvented in the daily conduct of the present generation' (55). Sartre is not unaware of the 'facticities' of an individual's birth. He insists however, that there is still choice in the way that these are interpreted. Thus, although individuals cannot escape their gender or social class at birth, they do not have to accept any specific notion of sexuality or social division. However, this possibility of ultimate, if rather hopeless, individual freedom is the only concession in Sartre's insistence that all action leads to forms of domination.

Sartre's contribution to a new concept of technology, therefore, is by way of his discussion of the relationship between individual action and structure. In this he reasserts the primacy of engaged action whilst acknowledging the emergence of social 'facticities' and the potential for autonomous change. Interest now becomes a dynamic attribute of individual action rather than, as in Habermas's work, a static category of social formations. Thus Sartre provides an alternative to the positivist concept of rational action by evoking the pragmatic context of action and recognising the need for structure to be continually reinforced. As a result he offers a way of developing Marx's concept of the dual relationship in the structuring process which allows for multiple forms of domination whilst at the same time, asserting the totality of society and allowing a degree of discontinuity and autonomy between its parts which does not rely, as does Althusser, on an ultimate dependency on a single institution.

However Sartre also demonstrates the dangers of over-emphasising the role of individuals. Thus, in spite of its interpretive role, his treatment of groups has led to considerable criticism. Because he allows the practico-inert no characteristics of its own, his ontology contains no category of we-ness to account for groups. They, like other structures, consist simply of the individual practices which have created them. In effect, according to Desan, Sartre fails to escape the Cartesian framework and remains locked into what Lefebvre (56) sees as the centre of bourgeois ideology, the myth of individuality which in Avineri's words 'ultimately reduces man to self-defeating hedonism' (57).

Recognising this criticism, Sartre went some way to acknowledging the difficulty and admits to '...... a specific reality of social facts'. These facts, such as money and language, are the 'product of the social activity of collective ensembles' and 'have their own structures and law that dominate individuals' but in the last resort they are still 'the reply of worked matter to the agents who work it' (58).

Giddens

Sartre's project of accounting for social structures and the relations between individuals and society is a fundamental topic for sociology, but, according to Thompson:-

> In the writings of most major theorists, from Marx, Weber and Durkheim to a variety of contemporary authors, this problem is raised and allegedly resolved in one way or another. Such resolutions generally amount to the accentuation of one term at the expense of the other ...... (59)

In the case of Marx, I have suggested that the basis for avoiding this one-sideness exists but is not fully exploited. Sartre hints at how this may be achieved but overemphasises individuality. Another attempt to develop the possibilities of Marx's work is to be found in the theoretical work of Giddens. As with Sartre, a fundamental concept for Giddens is the dual relationship whereby action creates social stucture which then becomes the context of further action. Thus he argues:-

> ...... that social structures are both constituted by human agency, and yet at the same time are the very *medium* of this constitution. (60 - author's emphasis)

He explains the relationship of these structures to the whole with the concept of structuration.

> The concept of structuration involves that of the *duality of structure,* which relates to the *fundamentally recursive character of social life, and expresses the mutual dependence of structure and agency.* (61 - author's emphasis)

In developing this concept, Giddens criticises both the functionalist and the structuralist uses of 'structure' for their failure to deal adequately with the time factor or to differentiate between the statics and dynamics of society. He finds typical British and American philosophies of action wanting because they treat it as a series of separate events rather than as a duration. For him, action 'does not refer to a series of discrete acts combined together, but to *a continuous flow of conduct*' (62 - author's emphasis). In this way, the discontinuity between past and present is abolished along with the artificial use of dates to identify historical periods and Giddens introduces the kind of flexibility sought by Bauman (63) who criticises Parsonian structures for their implication of a one to one relationship between structures and events. Although structure involves order, Bauman argues, it does not necessarily imply day to day predictability of this kind and any structure can lead to diverse events just as a particular event can result from more than one structure. It is the ability to account for this variability which Giddens tries to afford us with the concept of structuration.

Giddens uses 'structure' to refer to the rules and resources available to actors from a shared set of meanings and knowledge. The elements of structure may be described in the absence of any subject or time-space dimension but only have concrete existence within situated action. He acknowledges a static notion of time and space which makes it possible to identify the historical duration of a structure and the breadth of its application thus distinguishing strata of structures where the most enduring and all-embracing equate to the concept of social institutions. The constant emphasis of his argument however is that these structures do not enter into social action statically but shape and are shaped by their presence in practice.

The various structures available to one society create what Giddens calls a structured totality which incorporates:-

> ...... regularised relations of interdependence between individuals or groups, that typically can be best analysed as *recurrent social practices.* (64 - author's emphasis)

Such systems have structural properties but are not themselves structures. Rather:-

> ...... they involve the situated activities of human subjects, and exist syntagmatically in the flow of time. (65)

In this way Giddens dismisses the static/dynamic distinction between the structural properties of the social system.

Structure in this formulation is constraining, in the sense that it defines accepted practices, but it is also enabling in that it creates possibilities for action. An underlying feature of this relationship between action and structure is that the agent could always have acted contrary to accepted practice, but typically does not. Giddens explains this by identifying two aspects of consciousness in human agency; the 'practical consciousness' of everyday existence which assumes a particular structure of society and operates within it, and 'discursive consciousness' in which people rationalise their actions, although by doing so they may exclude unacknowledged conditions of action and its unintended consequences. Structures do not, therefore, embody preordination or inevitability and Giddens retains a place for both individual autonomy and the uniqueness of each action. We cannot therefore study history as a chain of causes and effects, rather explanation must account for an ongoing process in which one possible course of action is followed rather than another.

However Gidden's does recognise that

> ...... because of his concentration upon the critique of the political economy of capitalism, to which he gave over his life's work, Marx never managed to return to the more general problems of ontology that preoccupied him in the earlier part of his career. (66)

Thus Giddens intends his own work to take up this part of Marx's work and extend it beyond its limited concerns with economic production. Like Sartre, Giddens presents opportunities to develop a flexible and generalised concept of technology through the dual motion of structuration with its emphasis on continuous change and the uniqueness of events. He recognises the ephemeral nature of social structures which are only made concrete in specific actions and uses the distinction between types of consciousness to explain both the regularity of social action and its potential for creating change.

However, this position is not without its critics. Thompson (67) argues that the concepts of rules and resources which Giddens introduces do more to confuse the issues than resolve them because:-

a) they are imprecise and no more clearly defined in his argument than the concept of structure he seeks to replace,

b) they are applied to society as a whole and provide no basis for understanding differential applications to, say, different classes or sexes,

c) they do not provide the means for identifying things as being of the same type, for example, for defining that an institution belongs to a particular society.

The essential weakness however, according to Thompson, is that Giddens brackets out a level of social institution which is more global than that represented by the institutional rules and resources for particular types of action. At this new level, structure is not directly amenable to human action and therefore Giddens provides no explanation for the creation, maintenance and change of institutions at this level. Nor does he describe their relationship with the institutions which do concern him. Because of this, Thompson is led to question the emphasis which Giddens puts on the enabling aspect of structuration at the expense of an adequate treatment of the constraints it creates.

FOUCAULT - AN ALTERNATIVE TO MARX?

Rejecting the Positivism in Marx

Unlike the other authors discussed above, Foucault does not base his work on Marx. Indeed, his position may be explicated by what it rejects in the contemporary philosophies derived from Marx. Hence he:-

a) refuses to totalise his empirical findings into a grand theory and to explain them on the basis of an absolute philosophical system or concept of natural rationality,

b) denies any fundamental significance to human agency and rejects the idea of individual autonomy through reason,

c) rejects the idea that truth can be embodied in any particular group or social class,

d) denies that all forms of domination can be explained solely by economic factors or any other single cause,

e) rejects the subjective/objective relationship embedded in the idea that domination is best revealed 'on the basis of constituting the social field as one in which men and women act on things' (68),

f) warns against the imposition of one society's rationality on another (69).

In effect Foucault makes the case proposed earlier in this chapter that historical materialism as Marx applies it fails to escape the confines of nineteenth century liberalism because ultimately it retains the assumption of human reason and the subject/object dichotomy whilst creating new constraints through its limited basis of critique. Thus Foucault's position is fundamentally anti-positivist and his criticism of Marx derives largely from the latter's failure to escape that epistemology.

Foucault grounds his own position in Nietzche's emphasis on the diversity of modes of domination and the need to understand each historical and social instance on its own terms rather than by the imposition of a different socio-historical perspective or a calcified concept of natural rationality. Foucault adopts interaction in a symbolic world rather than the material world as a basis for social analysis which according to Poster is better suited to understanding twentieth century industrial societies.

Like Sartre, Foucault is responding to the mood of his time highlighted, in France, by the new movements of the 1960's culminating in the revolution of 1968. These demonstrated a broader base of opposition to contemporary society than that grounded in the experience of labour and the concentration of economic power. The demand being made was for a general democratisation of values and took form in racial, feminist, gay rights and ecological movements. Hence:-

> Instead of refurbishing Marxism with a more complex totalization, Foucault proposes a multiplicity of forces in any social formation, a multiplicity which is dispersed, discontinuous and unsynchronized. Social theory for him cannot grasp an entire social formation in one key concept or schema. It must rather explore each discourse/practice separately, unpacking its layers, decoding its meanings, tracing its development wherever its meandering path may lead. (70)

Discontinuity and Discourse

Foucault develops two key concepts which I propose to exploit in the reconceptualisation of technology. The first, discontinuity, allows him to spatially and temporally isolate social institutions as objects of study. Thus each one can be discussed in terms of its own logic of explanation without the need to explain either transitions from one state to another or the relationships between that institution and others. The second, discourse, explains the process of social change.

The explanatory role of discontinuity is demonstrated in 'Discipline and Punish' (71) where Foucault traces the history of punishment back from the present day to a point where its practice seems both irrational and barbaric by contemporary standards. He then explains the internal logic of the two systems of punishment, the first involving public torture and mutilation, the second imprisonment and the idea of correction. The method seems clear enough, but in reading the explanation offered by Foucault we come across contradictions which seem to pervade his use of it. Thus the differences between the two systems are represented as derivatives of the differing requirements of a feudal society needing to preserve the king's essentially arbitrary authority by a public display of power, and the post-1789 bourgeois society which emphasised rationality, individual responsibiltiy and property rights. However he does not explain why this broader change occurred nor does he use the characteristics of economy and efficiency associated with the new form of punishment to explain other discontinuities between the two social formations.

To escape the causality of positivist explanation in favour of this discontinuous notion of history, Foucault uses the idea of a discourse between power and knowledge. The main characteristics of discourse are described in 'The Archaeology of Knowledge' (72):-

a) it does not exist prior to its occurrence,

b) it is not subject to any process of natural development,

c) it exists only as it emerges in a specific conjuncture of knowledge and power,

d) the context of its emergence defines the subject of the discourse and the limits of its application although not necessarily the relationships which result.

Thus although discourse occurs at specific historical conjunctures, its results may be discontinuous with the objects and relations of its origin. The ephemeral and discontinuous nature of discourse and its constituents of knowledge and power, make them difficult features to locate within a social formation. Discourse is the locus of power but it occurs on a broad front such that it can only be identified in the concrete relations which result. According to Poster:-

> When discourse is theorized as the prominent feature of the social field, a new logic of domination is suggested, one that eschews the traits of the subject-object relation but follows rather the model of technologies of power. Historical materialism in the age of informational capitalism finds its premise in power that is the effect of discourse/practice. By the same token, the

> logic of discourse/practice finds its justification in the proliferation of information technologies. (73)

Hence, although knowledge occurs in symbolic form it is also to be found 'as practices that systematically form the objects of which they speak' (74). This is illustrated in 'Discipline and Punish' where Foucault says:-

> ...... this knowledge and this mastery constitute what might be called the political technology of the body. Of course, this technology is diffuse, rarely formulated in continuous, systematic discourse; it is often made up of bits and pieces; it implements a disparate set of tools or methods. In spite of the coherence of its results, it is generally no more than a multiform instrumentation. Moreover it cannot be localized in a particular type of institution or state apparatus. (75)

Hence Foucault's concept of knowledge fundamentally undermines the positivist notion of rationality and its assumption of the emancipating potential of knowledge as it is expressed, for example, in the work of Habermas. Instead it highlights the possibilities of knowledge as domination. He suggests, for example, that:-

> The human sciences project 'man' as their object and, with the intention of liberating that object, begin to control it in a manner not unlike that of the natural sciences. (76)

The assumption of neutrality of knowledge implicit in positivism masks the reality of this power and, as a result, Foucault is reluctant to acknowledge his own intellectual role.

The characteristics of power have much in common with this concept of knowledge. It too is diverse so that the relations of power are not 'univocal' but:-

> ...... define innumerable points of confrontation, focuses of instability, each of which has its own risks of conflict, of struggles, and of an at least temporary inversion of the power relations. (77)

Power is not to be found in binary oppositions but once again is diffuse, exercised rather than possessed. It is a property of relations rather than individuals or groups. Hence he argues that:-

> The logic is perfectly clear, the aims decipherable, and yet it is often the case that no one is there to have invented them ...... power and knowledge directly imply one another; that there is no power relation without the correlative constitution of a field of knowledge, nor any knowledge that does not presuppose and constitute at the same time power relations ...... In short, it is not the activity of the subject of knowledge that produces a corpus of knowledge, useful or resistant to power, but power-knowledge, the processes and struggles that traverse it and of which it is made up, that determines the forms and possible domains of knowledge. (78)

<u>Contributions and Difficulties</u>

Foucault's principal contribution to a new definition of technology is in his confrontation with the residual positivism in Marx. This arises firstly in his questioning of positivist rationality which obliges us in turn to question our own assumptions about individuality and the significance of human action. In this way we are led to recognise the dangers of imposing the rationality of our own time and place on others. In Marx's work, this applies in particular to his reliance on the rationality of the economic sphere to understand other social institutions. Foucault also questions the emphasis in Marx's work on production and labour and the assumption that the essence of humanity is action on an objectified nature.

By focusing attention on the concepts of discourse and discontinuity as a means of explaining social formations, Foucault realigns Marx's emphasis on the material basis of power within industrial societies and draws attention to other forms and sources of domination, in particular the possibility that control of language and information are as significant as control of capital. He also highlights the possibility of autonomous change within institutional logic which is not attributable to action; an idea which is inherent in Marx's position but not fully developed. His own use of the term technology through its association with power conveys the idea of technology as an abstract concept whose features are only made apparent by application to concrete situations.

However, Foucault's work also highlights some potential difficulties for the construction of a concept of technology. One is the result of his total rejection of any position based on Marxian concepts. As Poster illustrates, Foucault's own arguments would be strengthened if he drew on Sartre and other elements of the Marxist tradition rather than rejecting them outright. In studiously avoiding what he saw as the limitations of Marxism, Foucault created new ones of his own. Hence while Marxism bases its explanation of domination on the division of capitalist society into social classes defined by their economic relations to each other, Foucault avoided any categorisation of society and as a result could only provide explanations for society as a whole. His work cannot therefore differentiate meanings and experiences of domination within a society. His analysis of sexuality, for example, assumes that all women experience sexual domination in the same way because he denies himself the resources offered both by Marxist class analysis and Freudian individualism, whatever their other failings, to differentiate between the experiences of groups and individuals.

Foucault's work also appears to take on the ultimately pessimistic view of society to be found in the abstract meanings of technology discussed in chapter 2. Ellul (79), for example, sees no alternative to domination by technique although to interpret this as pessimistic, he suggests, is a reflection of the reader's values rather than his own. Both Heidegger (80) and Marcuse (81) also stress the pervasiveness of positivism although they each offer limited prospects of an alternative. However the logical conclusion of all their positions is illustrated by Noble (82) who argues that, for all its internal contradictions, the positivist epistemology is so firmly ingrained in industrial societies and their dominant elites, that it will be able to resist any world-view which might form the basis of an alternative society. Thus as Marcuse argues, the ultimate power of positivism lies in its ability to define what counts as valid knowledge.

Foucault's own pessimism, like Sartre's, is implicit in his argument that the only basis for understanding society is in terms of relations of power and domination. If anything, therefore, this pessimism is deeper because it is not just the positivist concept of knowledge which leads to domination, but all knowledge. As a result, any discourse will result in objective relations of domination and opposition to them will simply create different forms of domination. Poster suggests, however, that there is an alternative to this interpretation.

> If one rejects evolutionist progressivism because of its tendency to legitimize the present, the reasonable alternative is to focus on the limitations of all social formations. Such a strategy does not rule out a critical perspective that opposes domination; it simply reduces the promises of radical change. The existing form of domination is the one that is oppresive and must be resisted, even if there is no guarantee that a new form of domination will not arise to replace the old. The vision that emerges out of Foucault's writing is not necessarily pessimism, but it is one shorn of the dream of 'solving the riddle of history', of ending class society forever, of ridding the world once and for all of tyrants. To reject evolutionism is only to reject teleology, not the possibility of democratizing change. (83)

This more optimistic view is embodied in the concept of technology developed below.

The Question of Method

One further point highlighted by Foucault's work results from his attempt to break with conventional forms of argument, interpretation and the expression of ideas. One consequence is his unusual style of writing which appears to be vague, contradictory and evasive. Another is his refusal to totalise his work into a coherent theoretical position. In Poster's words:-

> He seems to take a perverse pleasure in shifting his stance, or simply in adopting provocatively an unorthodox attitude toward a topic. (84)

This style is a consequence of his attempts to avoid those features of Marx's work which he has criticised. The resulting implementation of his notion of discontinuity, however, often leaves the reader baffled by his apparent unwillingness to follow the implications of his own argument, to answer the questions it raises or to explain relationships between its parts. Thus when he argues that historians in their interpretive function assume power by their use of knowledge, we might expect, but do not find, an explanation of how his own position is different or why it should receive any greater credence. Nor do we find any recognition that his own work is a will to power or that it is a consequence of his own biography and historical context. Poster, by contrast, argues that:-

> The theorist can only propose the analysis of specific features of the social field, perhaps drawing connections between those features and other levels but no more than that. The totality remains a horizon of thought, never its object ...... At the pre-theoretical level, before the object of investigation is established or the categories developed, the theorist makes a choice. This choice concerns a political judgement about what is important in the present conjuncture, about what needs to be done, about the theorist's relation to his or her world and the relation of the theorist's work to this world. At this moment of theory formulation a form of totalization is implicit if not explicit. (85)

It is the failure to acknowledge this totalization in his own work for which Poster criticises Foucault.

We must recognise that his unorthodoxy underlies the fundamental value of Foucault's contribution to the current project by highlighting the paradoxes in Marx's work (86), but in doing so it also illustrates that revolutionary modes of thinking which attempt to break the mould of contemporary thought may be self-defeating if they are too complex and unrelated to existing ideas to take a hold in their readers' minds. It is here that Marx's evolutionary concept of change tempers Foucault's emphasis on discontinuity by recognising that there must be a cohesion and identity between the old and the new whereby the old adjusts as far as possible before finally giving way to the new.

The same charge of vagueness and imprecision may be levelled at the abstract uses of technology described in chapter 2. Winner (87), for example, finds this fault with Ellul's work although the latter argues that being descriptive, his work makes no value judgements and therefore has no need to provide a basis for action. The reason for vagueness in these examples however is not, as in Foucault's case, the result of a deliberate methodology, but a failure to take adequate account of the concrete instances of technology. Even where those writers recognise what Heidegger (88) calls the 'instrumental' and 'anthropological' aspect of technology, they assign it to a subsidiary and unimportant role in their theories. A synthetic concept of technology must account for both its concrete instances and their relationship to the abstract idea of technology.

Thus the essential challenge for the reconceptualisation of technology is to find ideas and language which clearly describe 'technology' in a way which is comprehensible to an audience steeped in positivist logic but without relying on that logic for its viability (89). The discussion above has suggested ideas which may be incorporated into such a concept and an appropriate methodology for using them. The remainder of this chapter will apply these in the construction of the sought after concept.

A SYNTHETIC CONCEPT OF TECHNOLOGY

The Nature of Conceptualisation

The key to the concept described below is the method by which it is constructed. The underlying difficulty with the meanings of technology examined in chapter 2 was that they were either too rigid and specific to be applied generally, or too broad and vague to provide a basis for specific applications. However the idea of a dual relationship developed by Marx, and its pragmatic application by Sartre, suggest a method whereby these limitations may be avoided. By adopting this idea, conceptualisation becomes the practical task of understanding; reflecting the pragmatic duality of the everyday activity by which human consciousness makes sense of the world of experience. In Bauman's words:-

> The continuous and unending structuring activity constitutes the core of human praxis, the human mode of being-in-the-world. (90)

The creation of a synthetic concept of technology in this chapter will be a formalisation of that everyday process of structuring in which it creates rules and resources (to use Giddens' terms) which can be applied to specific cases and adjusted in accordance with the resulting experience of their use.

This method of conceptualisation recognises that the world of our experience is too complex to be described in its entirety, even if the language was available to do so. Thus it accepts the need to impose structure, in the form of boundaries which delineate the subject, and categories which identify the units of description. Descriptions of the categories and the relationships between them constitute the resources offered by the resulting concept. However, it must be recognised that the boundaries and categories created for this purpose:-

a) have no necessary or objective reality,

b) must be supplemented by a description of those characteristics unique to the whole,

c) do not constitute discrete divisions of the whole but slices through its continuous gradations and complex combinations which provide alternative views of the subject at different levels of detail and together offer an understanding of the totality.

Even so, the boundaries being used have not been drawn arbitrarily but encompass a social institution which is part of the shared meaning of modern industrial societies. Thus the subject 'technology' will be seen to have a dual nature. On one hand it is distiguishable as an intuitively separate entity and at the same time, it will be described as an integral part of its host society which cannot be understood without reference to the social whole or have a history independent of it.

Within these boundaries three catogories or levels of analysis will be identified and the description of their contents and relationships will constitute the basis of the concept being constructed. These levels have been suggested by the discussion above and will be used in the attempt to synthesise the concrete and abstract attributes of technology within a single organic social whole. In this way it will be possible to account equally for the varying emphasis on action and autonomy in the works of Foucault, Sartre and Giddens, and to fulfil the promise in Marx's work of relating them to broader social changes.

The process of conceptualisation to achieve this will have three parts. The first will identify the categories being defined and describe the relationships between them. This will provide a description of the process whereby change can occur at one level of analysis as a result of contradictions at another. The second part will then identify a second process of change which results from the autonomous development of the logic operating at a single level of analysis, and any internal contradictions to which it gives rise. The final part will then consider briefly the broader implications of this description for a more general discussion of technology and society.

<u>The Concrete and Institutional Levels of Analysis</u>

The first level of analysis, which I have labelled 'institutional', embodies what Giddens calls 'rules and resources' for action. These are the structural characteristics and logic which give technology its institutional identity. Technology can never be fully described at this level because its abstract nature constitutes a focus of potentials rather than a fully delineated entity (91). Only at the second level, in their concrete application in action, i.e. in the creation and use of technological objects, do these potentials attain definite meaning. Thus the concrete and institutional levels of analysis enter into a dual relationship of the type identified by Marx and used by Sartre and Giddens. In this relationship action is generated from the shared institutional structure of meanings and knowledge which is then confirmed or contradicted by the consequences of that action. This may lead to a change in those meanings or knowledge which then become part of the resource for further action.

Thus structure defines the expected results of future actions and provides a model against which to match new experiences and through which to achieve a consistent and cohesive understanding of them. The unique content of each action in terms of time, place and the engagement of specific participants is an important element in understanding the significance of personal projects and freedom of choice in this structuring process. It does not mean that all action is necessarily rational (in the positivist sense) or purposeful, nor does it exclude the unintended consequences of action. However it does counter a static description of institutions and deterministic interpretations of the role of social structures in action. Structure then becomes both limiting and enabling. In Bauman's words, 'Structure means always the limitation of possibilities' (92), and it must be recognised that the limits created by structure constrain actors to view the world in a specific way. Yet because structure also gives stability through shared meanings and provides a means for actors to select relevant information within a constant stream of sense data, it also makes deliberate action possible (93).

The structure which results from the use of technology in action, therefore, is not simply imposed by people on the environment, nor is it derived from an objectively real environment, it is a pragmatic creation generated through the use of that structure in action. For it to be effective, it must have an essential correspondence with, and ability to explain, perceived reality. The crucial test of its value is whether the expectations it creates about the results of action are borne out in practice. The structure, and the process of creating it, are pragmatic in the same way that the categories being used in developing this concept are. Thus its viability is constantly in doubt and it must continually identify and adjust to new information which may reinforce or bring into question its assumptions. The importance of the concept of structure and its relationship with action is that it encompasses both the uniqueness of action, including the personal interests of those involved, and the regularities which occur through the existence of socially constructed, maintained and shared meanings. What it emphasises is the active rather than reactive relationship between people and their socio-natural environment. It highlights the twofold nature of that relationship which both constrains and enables human action.

This concept of a dual relationship does not fit easily into the logical structures offered by positivism. Hence, in his comments on Marx, Sayer (94) notes the difficulty of conceptualising trans-historical features which are only manifest historically, that is in specific actions, and Ruben (95) makes a similar point in discussing Marx's view of the relationship between thought and being. In reconceptualising technology, however, it is just such a relationship which provides for the possibility of an integrated account which synthesises its concrete and abstract aspects. Just as a full description of technology cannot be derived from its abstract form which only represents potentials, so the aggregate of all the concrete forms occuring in action cannot fully describe its potential because each takes only a part of that potential and applies it in a limited and definitive way. Instead, the pragmatic and dynamic relationship between these aspects of technology means that they are best explained by a description of the process by which they change, a process which, as we have seen, results from the concrete application of potential and the need to account for new experiences and the failure of expectations.

Change, therefore, may be defined as the resolution or negation of contradictions arising in praxis. In some cases the response may be immediate through the accommodation of the contradiction within the existing institutional structure. In other cases the contradiction may be suppressed or put to one side as a resource in the creation of an alternative structure. In yet other cases, the nature of the experience may be redefined so that it can be assimilated into the existing structure. As Marx demonstrates, that structure will use all the means available to adapt to contradiction and only change gradually until the accumulation of contradictions which it cannot adjust to becomes so great that the alternative logic, which has been forming to account for them, takes its place. At this point change becomes discontinuous leading, in Marx's terms, to a new epoch.

Change through praxis may be initiated at any point where technology is applied. The dual relationship described above creates the possibility that this will then be reflected in other concrete technology when the changed institutional logic is used as a resource in new actions. Through this concept of change, therefore, we are able to bridge the static/dynamic and concrete/abstract dichotomies which bedevil other theories. In retrospect we may identify technological changes as historical discontinuities, but this idea of change emphasises the internal integrity of each historical moment within a process of change which rejects the notion of history as a progressive series of causally related and discrete events.

The Social Level of Analysis

The critical contribution of a synthetic concept of technology however is not just in recognising the dual relationship between technology at the concrete and institutional levels of analysis, but in relating them to a third, social level whereby technology is integrated into the social whole. The social level of analysis reveals another duality in which technology is seen to be a specific implementation of the logical principles which provide cohesion and identity to a society. The relationship between the social and institutional levels of analysis, and the process of change it embodies are similar to those in the relationship between its institutional and concrete aspects. Thus structural principles which hold for the society as a whole provide fundamental rules and resources for the construction of technology's own logic although their application will be unique to technology. Just as each concrete use of technology in action has an element of uniqueness and autonomy but still retains its identity as technology, so technology embodies its own form of the social logic without losing its identity and cohesion within the social whole. Similarly, contradictions occuring at the level of institutional technology will require a response at the social level which may in the end lead to changes in the principles of social cohesion.

This concept of the relationship between technology and society does not mean that there is necessarily one global, socio-natural reality in which all people share. Numerous models are used in different social and historical contexts, and it is a common theme in social debate as to whether they have any common features (96). Within one society there may be conflicting notions of reality and each individual may be subject to multiple realities (97). Thus the concept of technology being developed in this thesis recognises a degree of autonomy which institutional technology enjoys in its relationship with its host society. This is a consequence of its specific implementation of the social logic and gives rise to the possibility of identifying and analysing it as a separate institution whilst recognising that the alternative realities, and the relationships between them occur within a coherent socio-natural ordering of the total environment and cannot be arbitrarily separated.

It is this social aspect which is missing in the action dominated theories of Sartre and Giddens and the institutionally dominated theory of Foucault (except in the weak concept of Episteme). Marx recognises it but locates it within a specific institution, the economy. Habermas's emancipatory interest is intended to play the role of social cohesion, but he is unable to sustain it in parallel with his rigid separation of the practical (institutional) and the technical (concrete) interests. Similarly Althusser identifies three aspects of society in which economy and ideology may be equated with the concrete and institutional levels of analysis and politics with the social. However, he not only retains the limiting concept of economy as the determinant of the last resort, but like Habermas, he also fails to retain the essential synthesising potential of Marx's position and reverts to idealism. By contrast, the different levels at which technology has been discussed in this chapter do not allow those levels to be discussed without recognising the complex relationship between all three and their ultimate grounding in pragmatism. Nor does it assume that they are definitive categories but uses them to exemplify relationships and a process of change which can operate at any point within the socio-technological domain.

Institutional Logic as a Source of Change

If we stop at this point however, we have still not gone substantially beyond Sartre's position whereby institutional technology is no more than an aggregate of the component actions from which it is derived. However Foucault highlighted the significance of change arising from the internal logic of structure itself, and the momentum for change independent of action which this creates. Foucault describes this as resulting from a discourse between power and knowledge, although his preoccupation with domination through the power embodied in structure excludes any significance for directed human action. In this reconceptualisation of technology, the role of praxis is reasserted but the contribution of autonomous change is retained through a restatement of the notion of discourse in which the potential for power inherent in structure is made distinct from the occurrence of domination. This allows for the possibility of non-dominating discourse and benevolent power which both Foucault and Sartre effectively exclude. This interpretation of discourse can also be seen as a generalisation of Marx's concepts of the forces and relations of production.

As Foucault demonstrates, the power and knowledge which constitute this discourse are difficult to conceptualise. They may indeed, as Sartre insists, originate in human action, but they have become disparate and apparently uncontrolled. We may be able to identify the implications of the logic constituted by discourse, but the origins of that logic, grounded in diverse and distant actions, with intended and unintended consequences, are impossible to trace. The resulting sense of being dominated by autonomous technology is discussed by Winner who suggests that the distress it entails is a consequence of the contradiction between our obvious dependence on technology and the assumption that we should be in control of the things we create (98). This situation is illustrated by the dependence of modern industrial societies on sources of mechanical power. As the original sources of that power fail, this dependence means that others must be found. Where, as in the case of nuclear power, this is seen as both necessary and unwelcome, the institutional and social aspects of technology have to respond to this contradiction in order to legitimate its use. This in turn leads to new concrete technology concerned with reinforcing that acceptance, for example by providing safety measures. Thus autonomous change, like that arising from contradiction in action, may generate its own momentum and lead to new concrete implementations.

Clearly, if we concentrated solely on the generation of change at the institutional level, it could be argued, as does Foucault, that resistance to particular examples of technology is fruitless because, in Winner's words, '...... a therapy that treats only the symptoms leaves the roots of the problem untouched.' (99). By recognising that change can also result from the negation of contradictions experienced in action, however, this reconceptualisation of technology acknowledges a role for individual actions. This possibility is grounded in the essentially pragmatic nature of structure which, because it exists to make action possible, remains viable only while it proves adequate in that role. Thus, although the contradictions in action may be diverse and individually limited, they may, if the existing structure cannot respond to them, achieve a critical mass at which discontinuous change occurs regardless of the apparent strength of technology's own institutional logic.

Hence, whilst power still resides as a potential of institutions and of the relations between them, the possibility also exists for powerful, directed actions either by individuals or groups. Even where single acts seem powerless, they may contribute to an accumulation which develops a momentum towards change. Also, because action involves engagement/interest, this view of power allows for the possibility that structure may favour, or be directed to the benefit of, the personal or group projects of particular members of society. This will result from the ability of those people to exploit or benefit from the power potential within structure. It recognises, therefore, that although action may take the form of critique, it may also be directed to reinforce the structure by parties whose interests it represents. Thus although, as Foucault argues, power is not the property of groups or individuals, but is a potential of institutions and the relations between them, it may be harnessed by a group, or coincide with their interests, although, as Sartre points out, this dominance must be continuously reinforced by new actions. Furthermore, this ability to harness power is always tempered by the unintended consequences of action, the autonomous logic of the institution, action designed to negate the contradictions of domination, and the ultimate requirement for a consistent and coherent explanation of experience.

Change at the Social Level

This discussion of autonomous technology can also enlighten our understanding of the relationship between technology and society. Within the conceptualisation of technology described above, social structure tolerates semi-autonomous and contradictory rationalities at the institutional level but maintains an overall cohesion within the social whole. Change in the principles of cohesion results from a similar relationship between the social and institutional levels as that between the latter and technological action. Change can therefore occur in two ways; as a consequence of contradictions occuring at the institutional level which require a response at the social level, or as a result of the momentum generated by the logic of social principles and their own internal contradictions.

In his description of capitalism, Marx does not maintain this distinction and as a result sees all social change as being generated through the relations of economic production. Althusser provides a broader interpretation using the concepts of 'structure in dominance' and 'overdetermination' whereby change can be generated in social institutions other than the economy although the latter still determines change in the last instance. Habermas, by contrast, moves away from the economy entirely and locates change within the political sphere. In contrast to these positions, the pragmatic basis of the synthetic concept of technology avoids the need to identify any dominant institution although it does allow that at any one time the pressure for change may be focused through a single institution. This may result in a progressive change in the principles of social cohesion so that they reflect the specific orientation of the dominant institution and cause sympathetic change in other institutions. In this way the logic of the dominant institution may seem to be translated into the logic of the society as a whole.

However, whilst this explanation provides a viable interpretation of the apparent dominance of technological thinking, the dual relationships embodied in the new concept of technology encourage us to recognise that social change is unlikely to be uni-directional. Thus, although mechanistic technology is the implementation of positivism most directly experienced by many people, it is not the only way in which positivism is experienced at the social level; it is part of a broader process of change involving, for example, religion and the economy. As Foucault's discussion suggests, therefore, power and knowledge are no more likely to be located in one institution than in a specific group and change is unlikely to be directed through any single source. Thus, whilst Marx casts an economically defined group, social class, in the role of vanguard of social change and Lukacs identifies intellectuals in this role, the synthetic concept of technology does not require such a specific identification. Hence any group or individual may be the source of change if contradictions arise out of their actions and even if technology is regarded as the most obvious focus of positivist principles and contradictions, fundamental change does not have to result from the actions of a group defined in terms of technology.

SUMMARY

The object of this chapter has been to construct a concept of technology which synthesises its concrete and abstract aspects in a way which an approach based on positivist thinking is precluded from doing by its own fundamental logic. It has used the work of a number of theorists as a resource in identifying both an appropriate methodology for reconceptualisation and the content of the concept. In the process, however, it has adapted and reformulated those ideas into a format which must be judged on its own merits not its pedigree.

The basis for the new concept was found in the work of Marx and took as its starting point his description of social labour; in particular the way it changes and develops within the total social context. A key element of this description is the dual relationship between the forces and relations of production within which technology provides an interface between people and their environment. This idea created the possibility of describing technology in terms of relationships and the ways they change and hence of achieving the required synthesis. The main features of Marx's position were identified in his description of the development of capitalism. In this he identifies contradiction as the main impetus leading to change and to an ultimate discontinuity between epochs. He also recognises, however, that existing structures will respond to contradiction and that revolutionary transformation will only follow a period of delay in which the accumulation of contradictions exceeds the structure's ability to adjust. Thus Marx was seen to demonstrate that simple causality cannot explain historical development except at the most superficial level.

In spite of the value of this contribution, there were seen to be limitations in Marx's position and two in particular were highlighted. Firstly, it was argued that his concentration on the economy and social production as the key to social relations and change, limits the value of his work for understanding other forms of domination. And yet, it is clear that other focuses of critique are relevant to twentieth century societies including domination through the control of information. Secondly, a residual positivism was identified such as that demonstrated by his progressive philosophy of history. These limitations were located within the context of Marx's contemporary experience of technology and his political objectives and it was acknowledged that these criticisms are the result of hindsight. His potential contribution to the reconceptualisation of technology was acknowledged, therefore, but was seen to reside in the possibilities which his methodology creates rather than in his own empirical conclusions. Consequently the work of other theorists was examined in the search for a reformulation of his ideas which could overcome his limitations.

Three uses of Marx's work were examined for this purpose. Firstly, the work of Sumner and Althusser was considered to reinforce the argument that Marx's analysis cannot be applied to present-day industrial societies without recognising its limitations. Secondly the work of Habermas was used to show that attempts to overcome those limitations, without retaining the integrity of Marx's methodological insights, also preclude the creation of the sought-after synthetic concept of technology by recreating the positivist dichotomies and lapsing into idealism.

The third use of Marx's work was demonstrated in the discussions of Sartre and Giddens who were shown to have addressed some of its limitations without sacrificing its essential insights. Both give a dominant position in their work to the role of action in the creation of structure and the subsequent use of structure in action; essentially the dual relationship discussed by Marx. Sartre reinforces this by replacing the positivist concept of rationality with the pragmatic concept of engagement and Giddens offers a new perspective on the abstract nature of institutional technology as a repository of rules and resources to be applied in action. However the emphasis on action by both authors was seen to have its own limitations. In Sartre it gives no place to institutional autonomy whilst Giddens cannot account adequately for a social level of analysis.

In contrast to all these approaches, which are fundamentally derived from Marx, the work of Foucault was seen to contradict the very foundations of Marx's theory. In doing so it highlights both the residual positivism in Marx's own work and its limitations for the critique of multiple forms of domination. Two key concepts developed by Foucault informed the reconceptualisation of technology in this chapter; discontinuity and discourse. Discontinuity breaks with causal explanation and allows social institutions to be understood within their unique temporal and spatial contexts. Discourse describes the process by which those institutions change emphasising the ephemeral nature of power and knowledge which are the principal constituents of that discourse. As a consequence Foucault was seen to attribute little significance to individual action and to emphasise the autonomy of change. Foucault's work gave rise to a number of difficulties, mostly deriving from his attempts to retain the integrity of his own position in the light of his criticism of Marxists. As a consequence, it was suggested, his style is frequently evasive and leaves unanswered questions. He is also unable to find any significant role for praxis, for differing experiences of domination or for a totalisation of institutional relationships at the social level. Thus, each of these contributions, both those making different uses of Marx and that of Foucault which rejects Marxism entirely, was seen to have limitations for the purpose of reconceptualising technology. Together, however, they provided the means to undertake that task.

The concept constructed from these sources was described in terms of the relationships between three categories; the concrete, institutional and social levels of analysis. At the concrete level, technology was described as the active implementation of the potentials and restrictions embodied in the institutional level. However the interactive relationship between the active and institutional levels meant that neither could fully define technology. The institution must always embody more possibilities than are actually implemented, yet these cannot be described except in terms of their concrete occurence. Through this dual relationship, therefore, it was possible to establish the mutual repricocity between the uniqueness of each action (resulting from the specificity of time, place and actor) and the regularity of everyday experience (resulting from the common institutional source of shared meanings). This was confirmed by a description of the process by which this relationship generates and transmits change. The essence of that process is the pragmatic application of institutional resources. Confirmation of the expected consequences of action will reinforce the existing institutional structure but contradiction will require it to respond, and possibly change. Where change occurs this may alter the resource which is available to future action. Thus their is a continual circularity of use and change informed by the purposes and context of action.

However, this relationship between the concrete and institutional levels of analysis could not in itself embody the totality of technology which also had to take account of a similar relationship between the institution of technology and the social whole of which it is part. The same relationship which exists between the concrete and institutional levels was also seen to operate here, and indeed at all other levels of the socio-technological domain. But change through contradiction at different levels was only seen to be one type, and, drawing in particular on Foucault, a second type of change was described. This results from the momentum generated by the autonomous logic operating at each level of analysis and through its own internal contradictions. The description of the new concept was concluded with a brief discussion of its implications for a broader social analysis, showing, in particular, that it did not require that any single institution or group should be the sole carrier of technological or social change but that it created the flexibility for examining the broad nature of such changes whilst recognising that they may, in practice or appearance, be focused for a time through a particular institution or group.

The process by which this concept has been developed was seen to be a formal application of the everyday process of structuring by which people make sense of their experiences. It therefore had to enter into the same dual relationship by which praxis, in this case a study of other authors, creates structural resources which can then be used in further action. This method carries the methodological implication, as Goldmann puts it, that:-

> The advance of knowledge is thus to be considered as a perpetual movement to and fro, from the whole to the parts and from the parts to the whole again, a movement in the course of which the whole and the parts throw light upon one another. (100)

The mistake of positivism is its lack of an historical perspective for which Marx criticised the bourgeois economists (101) and which leads Gadamer to argue that:-

> True historical thinking must take account of its own historicality. Only then will it not chase the phantom of an historical object which is the object of progressive research, but learn to see in the object the counterpart of itself and hence understand both. (102)

The use of this method, therefore, recognised the constraints it imposes, in particular its creation of artificial boundaries and categories which, although essential to the explication of the concept, can exclude as well as enable possibilities for understanding. In the pragmatic methodology which informs this conceptualisation, the value of those categories can only be seen in their application to empirical understanding. This chapter, therefore, must be seen as the first part of a process, which creates resources to be used empirically in the later chapters. To this end, the next three chapters will look at aspects of computer technology in order to demonstrate the value of the concept. Chapter 5 will look at the historical antecedents of modern digital computers to understand both the timing of their general acceptance and the form of their concrete implementation. Chapter 6 will then look at the process of developing commercial computer systems to identify the contradictions leading to change and the directions it has taken. In chapter 7, the mechanisms of resistance to these changes will be identified and then applied in a broader context where their implications will be considered in more detail.

NOTES FOR CHAPTER 4

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84. Ibid., p. 73

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86. In Zen Buddhism the use of nonsensical rhymes (koans) is used to highlight the paradoxs of conventional understanding.

87. Winner L. 'Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought', 1977, MIT Press, Cambridge Mass

88. Heidegger M. 1978 op cit., p. 302

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90. Bauman Z. 1973 op cit. p. 56

91. This is similar to the description of games given by Ludwig Wittgenstein in 'Philosophical Investigations', 1976, Blackwell, Oxford, pp. 31-33

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93. The evidence of this process is to be found in the methodology applied to the creation of this definition itself which is being undertaken in a specific time and place by a particular person and for a specific audience. Resources of language and ideas are being drawn on which at the same time make possible the communication of the definition and create limitations for its expression.

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97. My own experience in writing this thesis is an example of multiple realities - see chapter 1.

98. Winner L. 1977 op cit.

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CHAPTER 5

INTERPRETING THE HISTORY OF TECHNOLOGY

EMPIRICAL SUPPORT FOR THE SYNTHETIC CONCEPT

Chapter 2 demonstrated the difficulties which arise from the variable usage of the term 'technology'. In particular it showed that current uses tend to emphasise either its concrete or abstract attributes at the expense of the other. Subsequently both positivist and non-positivist principles have been explored in search of a means of synthesising these two orientations. According to the positivist epistemology described in chapter 3 technology is only incidentally related to the contemporary world in which it occurs. Different views may be held as to the source and status of technical knowledge, but technological change is invariably seen as a consequence of the independent and progressive development of new knowledge. An alternative view developed in chapter 4 sought to synthesise the concrete and abstract aspects of technology in a way not possible within the confines of these positivist principles. It represented technological change and the development of technical knowledge as the pragmatic and indexical consequences of a complex social reality whose various elements are mutually interdependent. Accordingly, new technology was seen to result from a discourse between social relations and knowledge. The required synthesis was achieved by locating this discourse within a set of relationships encompassing both action at the concrete level of analysis, and the rules and resources employed in action which reside at the institutional and social levels.

The second part of the thesis will now seek to demonstrate and provide empirical support for the ideas developed in the preceding chapters through their application to aspects of computers and their use. Specifically, the next three chapters explore the explanatory power of those ideas in terms of their ability to illuminate past, present and potential forms of computer technology. To do so they apply the notion of moving between different levels of analysis in such a way that each can enlighten the others. This method offers a resource to a potentially vast range of empirical projects ranging from the detailed analysis of a specific social process, such as the development of a particular computer program, to a wider ranging discussion at the institutional and social levels in order to explore the culture and ways of thinking which inform such processes. This thesis does not attempt to exploit opportunities at all these levels but concentrates on the social and institutional levels as a basis for the initial application of its concept whilst recognising the potential benefits of other empirical focuses.

The present chapter, which provides a discussion of alternative interpretations of the historical precedents of todays computers, serves to link the theoretical discussion which has preceded it and the later discussion of contemporary issues in the computer world. It does this firstly by reinforcing the rejection of the positivist basis for understanding and demonstrating the value of the synthetic alternative. In the process the three levels of analysis discussed in the theoretical development above recur in forms of causal explanations typically offered for historical events; that is the individual characteristics of significant actors (concrete level), the technological sophistication of their society (institutional level) and the effective demand for their ideas and inventions (social level). By emphasising the latter, the second linking element of this chapter is its reinforcement of the importance of the social level of analysis before the discussion in the next two chapters focuses on the institutional culture of computer technology.

The argument in this chapter will be developed in three stages. In the first, the nature of historical explanations based on the positivist and synthetic concepts of technology will be summarised. The second stage will then describe a number of events which typically are taken to have contributed to digital computers as they currently exist and the final stage will contrast the interpretations of those events offered by the two concepts previously described. This will demonstrate the limitations of the causal/positivist approach and the broader understanding offered by the pragmatic/synthetic alternative.

CAUSAL AND SYNTHETIC INTERPRETATIONS OF THE PAST

Historical understanding requires an appropriate language to describe events and the relationships between them. According to Elster (1), the causal mode of explanation involves principles of determinism, locality and temporal asymmetry. In other words, an event takes place because at a particular time and place there have existed:-

> ...... a determinate set of causal antecedents that are jointly sufficient and individually necessary for its occurence. (2)

This is essentially the same mode of explanation as that adopted by positivist science and assumes that events can be subsumed under general laws. Causal explanation therefore represents the past as a sequential unfolding of events within a unidirectional relationship described in terms of significant acts and actors. Its mode of explanation is essentially teleological so that the past is understood in terms of present meanings and past events explained in terms of the end-state to which they are seen to have led.

Some difficulties with the positivist mode of explanation were discussed in chapter 3. In this chapter it will be seen that the application of that method to historical understanding reflects those difficulties and creates its own peculiar problems. In particular, because it is not possible in historical analysis to confine a subject to an artificially constrained experiment, the causal method can never account for all the factors at work. Instead, we are left with the contradiction of a method seeking absolute definition and yet unable ever to identify final causes

(3). The object of this chapter is to illustrate the consequences of that dilemma for understanding the historical development of computers by contrasting the form of historical explanation offered by causality with that arising out of the pragmatic and synthetic concept of technology developed in the last chapter. (For brevity this concept will be labelled 'pragmatic' from now onwards.)

This latter view represents the past as a continuous process in which individual events are contextually circumscribed in complex interactions. Change is initiated through contradiction and momentum both at the level of action and within institutional and social logic. However there is no necessary or even identifiable relationship between the initiator(s) of change and their consequences. Technological change is not represented as the result of a natural progression of knowledge nor as the unfolding of a necessary sequence of events. Rather it seen as a pragmatic process of selection from available alternatives occuring within constraints created by the social principles which define the institution of technology and the society in which it exists. This form of explanation requires no final causes. Instead it acknowleges the integrity of each moment so that events are viewed using the criteria which defined them at the time they happened and the processes of which they were part. It does not therefore rely on a one-way relationship of cause and effect but the dual relationships of mutual development. Similarly, it does not concentrate solely on people and events which are retrospectively seen to have played a significant role in some present state. Rather it is able to account for events whose significance cannot be represented in a simple causal relationship but which none-the-less were part of the total context within which change occured.

To compare the explanations offered by these alternative forms of historical understanding, this chapter will apply them to a number of events and trends which are typically represented as being significant for the development of the modern digital computer. In particular it will look at the question of why machines and ideas available since the 1820's were not exploited for over a hundred years when, in the years since 1945, similar ideas and machines have become a dominating feature of industrial societies.

EVENTS IN THE HISTORY OF COMPUTERS

Charles Babbage - a prophet ignored in his time?

The earliest known reference to computing machinery was in letters written in 1623-4 by Wilhelm Schikard of Tubingen to fellow astonomer Johannes Kepler. The first authenticated working machine was produced by the French philosopher Blaise Pascal (4) in 1645 with others being made soon after by Samuel Moreland in Britain and Gottfried Leibniz in Germany. These early machines were little more than curiosities and they had no general impact even among scientists and mathematicians. However they represent one thread of the developing concern with calculation which was part of the revolution in scientific and mathematical thinking heralded by Galileo which had already seen the invention of logarithms (by Napier in 1614) and the slide rule (by Delamain in 1630 and independently by Oughtred two years later).

The first sustained effort to develop calculating machines was made by Charles Babbage (1792-1871). He was a leading figure in the revival of interest in mathematics and quantification which was part of the industrial revolution in Britain. As such, he was a founder member of the Analytical Society, which was in the vanguard of that revival, and demonstrated his interest in the practical application of mathematics through his membership of the Statistical and Astronomical societies. He won the latter's first gold medal in 1823 for his "Observations on the Application of Machinery to the Computation of Mathematical Tables". He also developed techniques which are now the basis of operational research, and published the first comprehensive treatise on actuarial theory, the first reliable life tables and a set of logarithms. An interest in engineering led to an association with Brunel and to major improvements in metal-working techniques through his foreman, Whitworth (5).

The social and economic philosophy which Babbage applied to his work is illustrated by his book "On the Economy of Machinery and Manufactures" (6) in which he advocates the principle of division of labour and the application of machines to both physical and mental tasks. He describes the production of logarithm tables in France where, by an appropriate division of labour, the bulk of the calculation could be performed by relatively unskilled labour. One of the continual themes of his career was the development of machines which could replace even this limited human participation.

Initially he received support for his project from the British government and the scientific establishment. His first efforts to construct a machine began in 1822 and shortly after he demonstrated a working model of his Difference Engine (7). He then began to build a much larger version of the machine which, with hindsight, demanded tolerances in craftmanship which were beyond those available to him, in spite of his efforts to encourage improvements. His lack of progress and deteriorating relations with his backers lost him his financial support and efforts to construct the Difference Engine were abandoned in 1833. However a more modest version was made in Sweden by Pehr and Edward Scheutz. This won a Gold Medal at the Paris Exhibition of 1855 and was bought by an American observatory. A copy was also bought by the Registar-General's Department in Britain for the production of life tables.

Far from being discouraged by the difficulties experienced with the Difference Engine, Babbage embarked on an even more ambitious project, the Analytical Engine. In many respects this embodied the first conception of the principles of the modern digital computer (8). This machine worked not on analogues of numbers but on digital representations which, in Babbage's words:-

> ...... converted the infinity of space, which was required by the conditions of the problem, into the infinity of time. (9)

In other words, large numbers would no longer need bigger and more complex machines to physically represent them in analogue form but could be processed by more iterations on their digital representation and therefore take time rather than space. Wilkes, one of the pioneers of modern computers was to say of this work that:-

> ...... Babbage was moving in a world of logical design and system architecture, and was familiar with and had solutions for problems that were not to be discussed in the literature for another 100 years ...... (10)

Even in the 1940's people working in the field of mechanical calculation were applying concepts which were cruder than those employed in the Analytical Engine. As with the Difference Engine however, Babbage's design was not only brilliant but grandiose, and it was never completed.

Data Processing Before the Second World War

We must recognise that while Babbage was concerned primarily with the development of calculating machines, the principal use of computers in modern industrial societies is data processing (11). For almost 80 years after Babbage's death computation and data processing followed largely separate paths and it is approriate to consider separately some of the developments which occured in the latter field.

The first real stimulus for mechanical data processing came with the need to speed up the production of results from the United States census. By the end of the nineteenth century, the information being gathered in that rapidly changing country was taking so long to process that the results were of little practical value by the time they were available. A competition to find a solution to this dilemma was won by Herman Hollerith and was based on the use of cards containing information as a pattern of holes punched into them (12). The principle of holding information in this way had been used as early as the fourteenth century for controlling the sequence of mechanical clocks. It had also been used by Jaquard to control looms and adopted from him by Babbage. Its implementation in the form of Hollerith's machines was used in the census of 1890 and produced the required results in six weeks.

Although Hollerith developed his machine not long after Babbage's death, he was already the beneficiary of better machining techniques and a greater knowledge of electricity. Equally significantly, the task he was attempting, and his method of achieving it, were simple in conception and execution. Unlike Babbage, he was not trying to provide the means for performing complex calculations. Rather, the requirements of the census work typify many commercial applications which perform simple arithmetic and logical operations, such as counting and sorting, but do so on large amounts of data.

It was not long before punched card machines (or tabulators as they were often known) found their first commercial application when the New York Central Railroad began using them for accounting in 1895. To benefit from this potential market, Hollerith left the US Census Bureau to start his own company which was ultimately to become part of IBM. His successor at the Census Bureau, James Powers, developed the machines further (13) until he too left to form his own company. From the turn of the century punched card equipment of this type was to become a normal part of the business scene and was only finally replaced when computers were generally accepted for use in commercial data processing in the 1960's (14).

Computation Before the Second World War

Although machine assisted data processing was more widespread than its computational counterpart during the first half of the twentieth century, the modern digital computer still emerged as a result of developments in the latter field. And yet it was over seventy years after Babbage's death before the principles he devised for the Analytical Engine were to be reunited in a single working machine. In the intervening period, however, a number of trends were developing which were to be realised in the construction of that machine.

One such trend was an increasing exploitation of the properties of electricity and the development of electro-mechanical devices. We have already seen one illustration of this in Hollerith's punched card machines. Another example was the work of a Spaniard, Leornardo Torres y Quevedo, who won a Gold Medal at the Paris exhibition of 1920 for a working model of an electro-mechanical version of Babbage's Analytical Engine. A second trend was the increasing role of science in the economy both as a basis for new industries and through ita application to research into new products and methods of production. At the same time there was an increasing use of mathematics and numeric representation of data, not only in science but in trade, accounting and government which, as we saw above, was being satisfied by punched card equipment.

A further trend was the development throughout this period of theoretical concepts and ideas which subsequently have been incorporated in modern digital computers. These are typified by developments of Boole's symbolic logic. Boole (1815-64) was a contemporary of Babbage who may have been acquainted with Boole's work which provides an 'algebra', that is a language, for expressing logical relationships (15). It was not until 1938 that the American Claude Shannon designed the first electronic circuits based on these principles, but since then it has become the basis of all modern micro-electronic circuit design and the formal logic used in computer programming.

Another significant conceptual development was the work of Alan Turing, a British mathematician working at Cambridge University in the 1930's. He defined the concept of a 'universal' machine which, in principle, could solve any problem of any complexity on the condition that the solution could be defined by a finite number of steps, each involving an elementary operation (16). As we shall see in the next chapter, the ability to define an algorithm, that is a set of instructions specifying those steps, has become central to methods of specifying and implementing computer systems. It also represents a significant conceptual step in the history of technology by which the 'universal' machine is not limited to a few physical operations, but, through its manipulation of symbolic representations, can become a different 'machine' with each new set of instructions.

Although Hollerith and Powers were able to take commercial advantage of their inventions in the data processing field from the beginning of the century, the various elements of future calculating machines described above did not coalesce into a marketable product until after the Second World War. In the meantime the demand for calculating machines was met largely by those with a direct need. In Britain L.J. Comrie, who was Superintendent of H.M. Nautical Almanac Office, used commercial punched card equipment for producing tables of future positions of the moon. W.J. Ekert, an astronomer at Columbia University, also devised a combination of punched card equipment for use in his work. In Germany frustration with the calculations needed for his engineering studies led Konrad Zuse to develop his first calculating machine which was based on magnetic relays and an ingenious form of input using holes punched in old 35mm film (17). In the United States Howard Aitken was equally frustrated by the effort required to solve differential equations for his doctoral thesis. Unlike Zuse, who had no major backing, Aitken was to receive help from IBM and from 1944 his computer was used by the United States Navy. He was subsequently to develop a number of versions of the machine and play a significant role in the develoment of computer technology in the post-war years.

The Spur of War

There is no question that exploitation of the potential demonstrated in the work of Zuse and Aitken was accelerated by the Second World War. There was a general increase in the sophistication of many branches of engineering. New aircraft and weapons announced the age of the jet and the atomic bomb, there were significant improvements in analogue devices such as gun and bomb sights and in electronics there were considerable advances in fields such as RADAR and communications. These developments reflected changes in basic scientific techniques two of which, in particular, contributed to and accelerated the development of digital computers. One was the sheer size of the calculations required by the new science and technology which was making standard methods of performing them impractical. The second was that electronics was becoming a fashionable solution to the new problems being made urgent by the needs of war. These factors came together in Britain in the development of Colossus, a machine built for the specific purpose of breaking German codes.

The essential technique for code-breaking was to identify patterns in the coded transmissions which would indicate the key to the code being used. Although sophisticated statistical techniques were employed, searching for these patterns was still a time-consuming process using conventional methods and was only made practical by electronic speeds. Colossus was a special purpose machine and did not have all the features which have subsequently come to be an accepted part of a digital computer. Even so, it was a significant advance in the use of electronics for computation and many of those involved with it were to play a role in the post-war development of computers in Britain.

However the details and success of Colossus were to be a secret for many years after the end of the war. As a result, the breakthrough in this field which was most publicised in the early post-war years was an American development, the Electronic Numerical Integrater and Computer (ENIAC). This machine used vacuum tubes as its principal method of storing the electronic impulses which represented its data. Like Colossus, it was exploiting a very expensive and untried technology which without the war may not have found a sponsor willing to take the investment risk. Originally designed for the production of artillery range tables, it was to be the training ground for many of the post-war pioneers of computer technology in America and to provide a public demonstration of the feasibility and potential of large scale electronic computers.

Some of the major advantages of electronic computers over mechanical calculation which it demonstrated were accuracy, flexibility in setting up problems, and the use of electronic components. The latter not only overcame the problems of tolerance in mechanical devices, such as those which dogged Babbage, but provided the possibility of mathematically determined error thus guaranteeing the replicability of results. However, as in Colossus, it was the speed provided by electronics which gave ENIAC its principal advantage over analogue alternatives. The use of electronics, which relies on switching between two states, together with the conceptual grounding provided by Boole and Turing, ensured that discrete rather than continuous representation of data became the norm for both the physical and logical design of computers and computer systems.

ENIAC itself was deficient as a modern digital computer in a number of respects. It was 'programmed' by a plug board rather than an internally stored program and its 'programmers' did not use many of the methods and principles which were to become standards for programming its successors. It also held its data in decimal rather than binary format and had relatively crude devices for entering information and recording results. These omissions, and its limited capacity for storing data, would be major drawbacks to the use of computers in data processing. ENIAC's designers, however, were more aware of its limitations in terms of its computational capability and, according to Goldstine, had:-

> ...... very specific ideas on the type of mathematical problems needing solution and on the logical design of a new machine to handle them as well as its engineering design. (18)

As a result, much of the development work immediately after the war concentrated on the computational potential of computers and led to a variety of new machines both in the United States and in Britain.

In this period of establishing the conceptual basis of modern computers the work of John von Neumann was particularly significant. Von Neumann was a mathematician whose interest in computers was essentially in their ability to solve mathematical problems. For him, therefore, the algorithmic approach was a natural choice for the basic principles to be adopted in this new field. His special skill, according to Goldstine, was the ability to clearly express those principles as they were being established by the pioneering work in which he was involved. Goldstine directly attributes to him two very significant advances. The first was to recognise that it is the logical operations taking place, and not their electronic representation, which is the significant feature in realising the potential of computers. The second was to identify the importance of the stored-program concept. This means that the complete set of instructions for performing a calculation should be held in the computer in its entirety rather than fed in sequentially. In this way the instructions can be altered according to the intermediate results of the calculation giving an important flexibility to the processing logic.

These principles, commonly referred to as the 'von Neumann architecture', have remained the model for almost all data processing engineering to the present day. Only recently, with the need for even greater processing power than is possible with von Neumann's architecture, have alternatives been considered. However, even in 1950 it was not the only model available. The possibility of alternative approaches was demonstrated by Norbert Wiener in 1947 in his book 'Cybernetics'. Wiener first formulated his ideas when he was working on the design of a control system for anti-aircraft guns which maximised the chances of hitting an evading target. He began, not from Turing's universal machine, but from a concept of 'information' which embraced notions of control and communication which are equally applicable to machines and people. Thus the same principles can be applied to a management reporting cycle, an automated industrial plant or the human nervous system.

In Aleksander and Burnett's words:-

> ...... Wiener was already well aware that the arrangement of electronic switches proposed by von Neumann was only one of a whole range of possible 'architectures'. Indeed Wiener's whole approach to the possibility of information processing machines was quite different to that of von Neumann and the other computer pioneers ...... Certainly when it came to planning the structure of the computer the mathematicians and engineers did not look to nature for a model; instead the arrangement adopted was dictated by the idea of a computer as a programmed machine that would resolve mathematical and logical problems. (19)

However it was the von Neumann model which predominated and by the early 1950's the essential elements of modern digital computers had been defined and demonstrated. The main limitations on their widespread use were inconvenience and the expense of the engineering involved.

Post-war Developments in Data Processing

Although computers have revolutionised the possibilities of science in the post-war years, their most direct social impact has been in the field of data processing. Even though computation remained the primary use for computers immediately after the war, some of the first commercially available machines were used in non-computational roles. The LEO (Lyons Electronic Office) was used by J. Lyons in Britain from 1950 and the United States Census office installed a Univac machine the following year. The spread of computers for data processing was delayed initially by IBM's reluctance to enter the field which it already dominated with punched card equipment. However the industrial boom which paralleled the Korean War finally brought it into this new market which it was also soon to dominate.

The transition to using computers for data processing involved a number of avenues of development. Perhaps the most significant early breakthrough was the conceptual realisation that the information used by science is only one form of data and computation only one possible type of data processing. It is not possible to identify a moment when this realisation occured, rather it represents one aspect of the process which saw an increasing willingness to subject non-numerical data to the same logical processes as were used by mathematicians. Technically this became realistic with the implementation of symbolic logic in electronics which demonstrated both that information could be stored as electronic bits and that arrangements of this logic could be set up to represent conditional constructs (20).

However the possibility of a more general use of computers for data processing was also improved by other developments. In particular, changes in engineering meant that computers became more reliable, cheaper and more convenient in terms of size and heat output. In other words they became mass market products (21). Another field of development was in the engineering of devices peripheral to the central processor to make the input, output and long-term storage of large volumes of data more convenient. One of the major differences between computation and commercial data processing is that the former does large amounts of processing on relatively little data whilst the latter does a little processing on large volumes of data. Hence the importance to a viable data processing machine of devices such as fast paper-tape and card readers, printers and magnetic storage on tapes and drums. Progress in this direction was not smooth however, partly because most innovation still originated in the universities who retained a computational bias. Hence, in 1964, one commentator noted that:-

> No clear, general formulation of business requirements, an experimenter's disdain for costs, and continual advances in electronics, have caused the development of A.D.P. machines to be dominated by technical factors. One of the more significant has been the continued mismatch between the speeds of calculation and of entering and removing data. (22)

However it was not only hardware developments which could resolve these difficulties. Increasingly the basic architecture of machines involved a mix of hardware and software (23). The software element, the machine operating system, was created to interface between the physical operation of the machine and the programs using it. One of its functions was to overcome the discrepancy in speed between the central processor and the peripheral devices for inputting and outputting data. Until this could be done, the benefit of electronic speed for data processing was always limited by the performance of the electro-mechanical peripherals. The essence of the solution was to separate the execution of a program from its communication with slow peripherals. To achieve this, a fast peripheral such as a magnetic drum, was used to interface between the processor and the slower peripherals such as card readers and printers. The data to be input was transferred to the faster device prior to program execution and its results written back to it for subsequent output on, say, a printer.

In itself this technique could not reduce the overall time taken to execute a program and a parallel development in operating systems also gave them a facility to share the time of the central processor between a number of programs. Thus, while a main program was processing, reading and writing its data from fast peripherals, other programs could use the short periods when it was waiting for a transfer of data to do other processing. These programs would typically be printing data left by a previous program or reading data from cards to be used by a later one. We can see how from the beginning, therefore, the technical contradictions of electronic data processing were being resolved by the standard positivist technique of reducing a complex operation to its component parts and rearranging them without radically altering the final result.

Another area in which the use of machines was being made easier was in the development of programs, particularly the languages in which they were written. This was important for commercial data processing if organisations were to be able to develop their own programs. Increasingly the object of language design was to hide the programmer from the task of physically controlling the hardware or understanding the basic principles of the computer's operation. This detachment was achieved by letting the programmer write in a code which was then translated into instructions which could be executed by the machine (24). The earliest languages reflected the still dominant interest in computation; hence FORTRAN (formula translator) was introduced in 1957. However by 1959 work was also beginning on the definition of COBOL (Common Business Oriented Language) which has become the standard language for most commercial installations.

These developments began to have a significant impact by the mid-1960's when they could take advantage of increases in the power of central processors which ensured that the extra processing required by high-level languages and the operating system did not detract from the performance of the users' programs. Since then the use of computers has become almost compulsory for all but the most limited data processing operations. With the introduction of personal computing (25) many of these are also succumbing.

APPLYING THE ALTERNATIVE INTERPRETATIONS

Causal

In terms of developing an understanding of technological change, the main point of interest in the series of historical circumstances described above is not so much the detail of the technical developments, but why the machines and ideas produced by Babbage were not taken up more enthusiastically by his contemporaries when similar ones have revolutionised modern industrial societies. If we adopt a causal mode of explanation, this will require the identification of necessary cause(s) which were absent in the first instance and present in the second. In discussing Babbage, Mowshowitz suggests three causes which may be relevant.

> The computational needs of the nineteenth century were not seen by his contemporaries to warrant the dedication of resources required for such a project. In addition the technology of the period was inadequate, perhaps even inappropriate, to the task. Babbage's continual modifications in the design also complicated matters. Too much a visionary, he could not compromise his grand design to translate possibility into feasibility. (26)

Thus Mowshowitz has selected effective demand, the state of engineering knowledge and Babbage's own personality as elements in a causal explanation (27).

Refering to Babbage's personality, Bowden comments that:-

> It was the tragedy of the man that, though his imagination and vision were unbounded, his judgement by no means matched them, and his impatience made him intolerant of those who failed to sympathize with all his projects. (28)

There is no question that Babbage alienated those who had lobbied for, and provided, his early financial support, both by his attitude to them and by the lack of results from his efforts. Consequently he was not the best person to encourage a general understanding or acceptance of either his conceptual achievements or the practical potential of his machines. If we compare this with the circumstances after the Second World War, we find that there was a key figure, von Neumann, who was able to communicate the essential concepts of the digital computer, and others who were able to demonstrate the engineering practicality of implementing them. However the argument based on Babbage's character loses some of its force in view of evidence that others were available to perform the role of advocate for him. As we noted above, at least two Difference Engines were put to practical use, one in Britain and the other in America. Babbage also had the assistance of the colourful Lady Lovelace who produced both an excellent description of the Analytical Engine and, by repute, the first computer program (29).

Mowshowitz's second line of explanation is the inadequacy of the technical knowledge and skills available to Babbage. Writing in 1953, Bowden (30) doubted whether it was possible even then to produce a mechanical device of the complexity envisaged by Babbage. When his ideas were implemented in later years by

Torres, the latter was able to employ electro-mechanical techniques and the real breakthrough which led to the modern digital computer came with electronics. An explanation in terms of available knowledge, therefore, seems more convincing than one based on Babbage's personality. However this still cannot explain why no major effort was made to solve the technical problems he faced, or to develop his ideas once those problems had been solved in later years. For example, one possible basis for a computer was available as early as 1914 when the Bell Telephone Company considered the use of the mechanical switching devices used in telephone networks as a means of storing and processing data. However it was not until the Second World War that such a device was built. We have also seen that Torres had produced a working electro-mechanical version of the Analytical Engine by 1920 and, as Randell comments:-

> ...... there seems little reason to doubt that, should the need have been sufficiently pressing, Torres would indeed have built a complete analytical engine. As we shall see in later chapters, it was not until the 1939-1945 war that the desirability of large scale fully-automatic calculating machines became so clear that the necessary environment was created for Babbage's concept to become a reality. (31)

Of the causal explanations suggested by Mowshowitz, therefore, the most feasible would seem to be the lack of an effective demand for the facilities Babbage, and later Torres, were offering. If an effective demand had been available during his lifetime, we might have expected greater efforts to overcome the barriers created by his own personality and the limits of technology, or at least to make more use of what had been achieved by the Scheutz's. Instead, the demand for calculating machines by Babbage's contemporaries was much as it had been since Pascal and Leibniz first produced their machines in the seventeenth century, that is to reduce the drudgery of calculation especially in the production of tables such as those used by astronomers. Napier's publication of logarithms had been similarly motivated.

> Seeing that there is nothing (right well beloved students of the mathematics) that is so troublesome to mathematical practice, nor that doth more molest and hinder calculations, than the multiplications, divisions, square and cubical expansions of great numbers, which beside the tedious expense of time, are for the most part subject to many slippery errors, I began to consider in my mind by what certain and ready art I might remove these hinderances ...... (33)

Even by the 1930's the motivation for constructing calculating machines was largely as it had been for Pascal, the need to solve an immediate mathematical problem. Hence those produced by Aitken and Zuse were both built initially to deal with the mathematical problems raised by other fields of study. Similarly, ENIAC was originally built to calculate artillery range tables (33) and Babbage's own interest in mechanical calculation was stimulated by their potential for the automatic production of logarithm tables rather than by possible commercial or industrial applications. It was only with the emergence of 'big' science during and after the Second World War, and the direct government involvement which that entailed, that a general demand for calculating power became effective (34). Meanwhile the demand which had developed for automatic data processing in commerce and industry was being met by a different type of solution in the form of punched card machines.

There is certainly a case, therefore, for arguing that lack of demand can explain the failure of his contemporaries to take up Babbage's ideas with more enthusiasm. However this type of explanation only leads us to ask more questions both about why the demand was not there and why it was to develop subsequently. The same difficulty arises in explaining the course of post-war developments. What causes, for example, explain the adoption of the von Neumann architecture rather than the cybernetic alternative, and what factors brought about the developments in operating systems and programming languages? In each case an explanation based simply on causation can at best be partial and can never grasp the totality of its subject.

Synthetic

The alternative form of historical explanation derived from the concept of technology developed in the last chapter suggests that the limitations of causal explanation may be overcome by recognising the pragmatic nature of the historical process. As that discussion observed, some structuring is inevitable if understanding is to be achieved. In historical studies it is convenient to create that structure by relating a series of historical events in terms of a common theme such as the development of calculating machinery. However the synthetic concept of history demands continual awareness of the vulnerability of such structures lest their convenience be mistaken for some necessary feature or process of history. This does not deny the significance of specific features such as the role of individuals, the availability of knowledge or the existence of demand. Nor does it deny the enabling effects of the concurrence of a number of such features. However it interprets these features in a context where they are not independent parameters of a discrete event, but part of a complex process occuring over time. Wilder makes a similar point in the case of mathematics when he argues that:-

> At any given time, there will evolve only concepts that are so related to the existing mathematical culture as to increase its utility in meeting the demands of either its own hereditary stresses or the environmental stresses from the host culture. (35)

One possible means of overcoming simplistic causal explanations is suggested by Pinch and Bijker (36) who use the concept of 'relevant social groups' to explain the direction taken by technological development and the possibilities excluded on the way. Relevant social groups consist of people with a similar perception of an emerging technological artefact, each of which will identify different 'problems' with the new artefact and a number of possible solutions to that problem. The process of selecting which problems will be solved, and which solution chosen, is shown to involve not only 'technical' evaluations but 'non-technical' considerations such as morality and legality. Pinch and Bijker see this approach as the beginnings of a social constructivist approach to technology, that is one which looks at the social derivation of not only the 'use' of technology but also its 'content'. In this they take their lead from developments in the sociology of science. Although they use a different conceptual framework from the synthetic concept of technology developed in this thesis ('problem' rather than 'contradiction', 'closure-mechanism' rather than 'response to contradiction'), there are grounds for suggesting that the two approaches are complementary. Thus it would seem that the synthetic concept takes the work of Pinch and Bijker a stage further by seeking to identify not only direct social influences but to locate the construction of problems, and the prediliction to certain solutions, by these influences within the broad social context of their occurence.

However, while the consequence of the causal approach is that all events in an identified chain are interpreted in terms of the concepts and realities of the historian's present. The synthetic intepretion is in terms of the context and categories pertaining at the time of the event. Thus it can accommodate a fundamental asymmetry between the cultural and epistemological environments of Babbage's nineteenth century Britain and the mid-twentieth century. In Foucault's terms it accounts for the discontinuity between the two periods which makes the meanings and categories of one inappropriate for understanding the other. It allows, therefore, that although Babbage's society was undergoing rapid industrialisation, the habits and cognitive style that have come to dominate modern industrial societies were not yet established. Indeed Babbage himself was instrumental in making the case for the application of mechanistic thinking to industry. Hence we cannot argue that had the same people and techniques been available in his time as were to be found in 1945, his ideas would have been taken up. This is not simply because there was no demand, but because it would deny the essential incompatibility of the nature of digital computers and the cognitive style which dominated nineteenth century Britain.

Although this idea of discontinuity is a useful shorthand, however, we must be wary of assuming that there is a single identifiable point at which the transition occured. It was not a sudden event but the culmination of a long process of change which we now label the 'Industrial Revolution' (37). The nature of that process is illustrated by the typical motivation for technological change which in the nineteenth century was essentially application oriented, whereas in the twentieth century it is typically based on the implementation of generalised principles. Thus, in the earlier period, most technical developments resulted from practitioners applying their experience to the resolution of the specific contradictions which they experienced in their own workplace or industry. Their motivation was economic not scientific (38). The application of general principles was still not the broadly accepted way of developing knowledge relating to industrial equipment and processes. As Flinn comments:-

> There is a strong case for arguing that industrial technology and scientific research proceeded on independent if parallel lines for a century or possibly more after the foundation of the Royal Society [1754]. (39)

A key feature in the transition to general principles was the broader application of 'scientific' methods and particularly the language of mathematics. In Babbage's society, concern with mathematics was limited to a few occupations such as engineering and navigation although one of his own contributions was to stimulate a wider interest in its practical applications. There were also indications of a developing concern with the collection of information and its numerical presentation. The first national census was taken in 1851 and more sophisticated mechanisms of financial control were being developed in the form of limited liability companies, the rationalisation of financial institutions such as banks and the Stock Exchange, and the growth in industrial units beyond the size which could be controlled by the individual entrepreneur. By the twentieth century the trends had gathered considerable momentum and, as Mowshowitz notes:-

> The rapid diffusion of computer applications in the post-war period is not a historical accident contingent upon the chance creation of a single instrument. Both the disposition to use the computer and the particular areas of its application have been conditioned by prior developments ...... Perhaps the key to understanding the present disposition of computer applications lies in the fact that advances in computing technology accompanied the growth of large-scale industrial enterprise and centralised government administration. (40)

However, in the nineteenth century, as Pollard (41) points out, forms of commercial accounting were still very simple and managerial knowledge, like industrial innovation, was restricted largely to the running of a particular industry rather than the application of general principles. Most critically, perhaps, the conceptual link had not been made whereby it was natural to apply essentially computational tools and logic to non-computational or simple arithmetic data processing requirements. This gap between the mathematical needs of scientists, which led them to develop calculating machines, and the data processing needs of industry and government resulted in their largely separate development throughout the first half of the twentieth century.

The construction of digital computers beginning in the 1940's therefore was not so much the culmination of a series of necessary stages of technical innovation as the maturation of a conceptual development which established positivism, especially scientific and technological thinking, as the basis for the principles of social cohesion. The development of data processing after 1945 illustrates a very different situation from the period before the Second World War. The synthetic method suggests, therefore, that a crucial element in the merging of the computational and data processing streams of development, to the point where they used the same machine architecture, was the creation of this mutually compatible environment in which both could apply the same logical principles to their operations. This had emerged as the culmination of the trends which were described above and led to the establishment of the von Neumann architecture. Basic concepts based on the algorithmic principle were then applied to both the engineering of hardware and the construction of software. Thus the response to the contradictions being experienced in the commercial use of computers such as slow peripherals and lack of mass storage, was confined within this mechanistic paradigm which consequently generated its own momentum.

A similar argument can be applied to explaining the failure of Wiener's ideas to have an impact on the fundamental architecture of computers in the 1950's. Rather than an explanation in terms of his personality, technical feasibility and demand, the synthetic view recognises the discontinuity, that is the essential incompatibility, between the principles which he advocated and the algorithmic principles supported by the dominant mathematical/engineering culture in which the first machines were developed.

Thus, although complexity of historical processes requires that a synthetic interpretation of past events be structured in order to make it comprehensible, the status of that structure is very different from the one imposed by a causal explanation. The events it describes are linked not by chronological causality but by changes in institutions and social principles resulting from contradictions and momentum in action and institutional logic. To understand why Babbage's contemporaries were not even aware of the opportunity they were missing, it judges them not by the categories and values of societies which have grasped that opportunity a century later, but in terms of the categories and values of his own society. The process by which simliar ideas subsequently came to be adopted and then developed is to be understood in terms of the momentum generated and the contradictions emerging in the intervening and subsequent periods. In this sense we cannot say that the opportunity for computers as we now know them even existed at the earlier time.

SUMMARY

This chapter has started to explore and assess the benefits of the synthetic concept of technology constructed in the last chapter. It began with a summary of the forms of historical explanation offered by that concept and an alternative derived from positivism. It followed with a description of some events and trends typically associated with the historical development of mechanical computation and data processing. It then compared the understanding of those events and trends offered by the pragmatic/synthetic and positivist/causal concepts of technological change. It focused particularly on the question of why machines and ideas developed by Babbage in the nineteenth century were largely ignored until they were subsequently incorporated into the digital computer which has since become a dominant feature of modern industrial societies.

Typical causal explanations in terms of personalities, the availability of knowledge and effective demand, were examined and found either to have limited support or to leave questions unanswered. These difficulties it was suggested arise from its uni-directional and telelogical mode of explanation which is unable to account for the complexities, discontinuities and contextual uniqueness of the historical process. It was not suggested that the elements identified in causal explanation are not significant, rather that the structure it imposes on them is unsatisfactory.

The synthetic approach was seen to offer the opportunity to overcome the limitations of causal explanation. It does so firstly by recognising the importance of the total context within which historical events occur. This allows for the interaction of disparate social functions through their common identity in the principles which bind their society. It also recognises the potential for discontinuity between that context and the one in which the historian undertakes his work. Finally, it does not limit the historian's view to those people and events which, with hindsight, have proved significant. Change is a process of selection between alternatives. The direction taken is constrained by the social context in which it is chosen and the same explanation can be used in understanding the paths which were not followed as in understanding those which were. Thus we can explain the development of modern digital computers both by identifying the culture of the von Neumann architecture from which they are derived, and by explaining why Wiener's cybernetic alternative was not acceptable. As with Wynne's discussion of Barkla (42), therefore, understanding is focused not on the 'technical' or 'scientific' validity of a particular idea or machine, but on the social process in which it is accepted or rejected.

This application of the synthetic concept of technology has demonstrated the value of its flexibility and comprehensiveness in developing historical understanding. However it is implicit in that concept that understanding of the present and all possible futures will be derived from the same pragmatic relationships through which the past has developed and will, therefore, be subject to the same mode of explanation. Because it acknowledges no natural or progressive logic which gives special status to present knowledge, except in so far as it is currently pragmatic, so each moment in time has the same potential for change as the last. The next two chapters will explore this mode of understanding, firstly in relation to contemporary changes in computer technology, and then to a consideration of the future implied by the continued application of positivist principles to computer technology.

NOTES FOR CHAPTER 5

1. Elster J. 'Explaining Technological Change', 1983, Cambridge University Press, Cambridge

2. Ibid., p. 27

3. Sartre creates much the same problem with his insistence that all social entities must ultimately be explained by the human actions which created them.

4. A popular computer language has been after Pascal.

5. He is also credited with the design of the cowcatcher featured on American railway engines of the period.

6. Babbage C. 'On the Economy of Machinery and Manufactures', 1835, Charles Knight, London

7. This is named after the mathematical principle on which it is based.

8. The main ones being:-

   - A Mill - a mechanism for performing arithmetic
   - Memory - for the storage of intermediate results
   - A library of routines for common functions
   - A control unit - which allows conditional branching
   - Input - punched cards
   - Automatic printing of results

9. quoted in Randell B. (Ed.), 'The Origins of Digital Computers', 1982, Springer-Verlag, Berlin, p. 11

   An analogue represents a value as a physical quantity such as voltage or, in Babbage's case, as teeth on a cog. A digital representation is a code for the value. Hence 10 may be represented as an analogue by the distance between the x's x   x, and digitally as 10 (the decimal code), as 1010 (the binary code) etc. For an analogue device like Babbage's Difference Engine to process larger numbers, the machine had to increase in size to accommodate the larger number of cogs. For a digital machine like the Analytical Engine which achieves multiplication and division by repeated addition and subtraction respectively, processing larger numbers principally requires an increase in the time taken for the increase in additions and subtractions.

   One example of this distinction is wrist watches which may be analogue, ie. represent time as distance round the clock-face, or digital, ie. represent time as numbers.

An important implication of the difference is that digital representations are always in units and therefore discrete whilst analogue representations are potentially continuous although in practice the mechanism producing them may create units, eg. teeth on a cog.

10. Randell B. 1982 op cit., p. 11

11. The principal distinction between commercial data processing and computation is that computation normally performs complex processing on a limited amount of data whilst data processing normally performs a simple procedure on a large amount of data. This distinction is necessarily simple but is sufficient to explain both their separate paths to mechanisation in the first half of the twentieth century, and the contradictions which shaped the development of computers to meet data processing requirements after 1945.

12. The size of the standard 80 column card used by IBM began with Hollerith who based it on a Dollar bank note.

13. The main reason for these developments was an attempt to circumvent the patents held by Hollerith.

14. Some attempts were made to use this type of equipment for scientific purposes (see below) but its limited calculating powers made this largely untenable.

15. Typical Boolean operators are AND, NOT and OR used in statements such as:-

    - IF X is true AND Y is true THEN Z is true - which defines a relationship in which both conditions are required for the result to occur

    - IF X is true OR Y is true THEN Z is NOT true - which defines a relationship where if either of the conditions is met the result does not occur.

16. This will be recognised as an application of one of the principles of positivism described in chapter 3.

17. Those who would take the regression of causal analysis to its logical conclusion might like to identify the chain of causality whereby Zuse and his chief collaborator were originally brought together by a common interest in King Kong.

    It is not clear how far Zuse developed this work and in the aftermath of the Second World War it was largely forgotten.

18. Goldstine H.H. 'The Computer from Pascal to von Neumann', 1972, Princeton University Press, Princeton, p. 186

19. Aleksander I. and Burnett P. 'Reinventing Man', 1983, Penguin, Harmondsworth, pp. 107-8

20. There are a number of conditional constructs, eg. 'IF x is true THEN do y ELSE do z', and 'WHILE x is true DO y'. The conditions (x) are typically stated in Boolean terms, eg. (p AND q) OR r. The significance of these constructs can be seen from the fact that in the technique known as structured programming (see chapter 6) all possible requirements are reduced to four or five such constructs.

21. The term generation is used to represent changes in the principal form of circuitry, ie.
   - 1944 to 1958/9 - various types finally settling by about 1953 on vacuum tubes
   - 1958/9 to 1969 - Transistors
   - 1967 to date - Solid state integrated circuits

   Some would add a fourth generation for the very large scale integrated circuits which made micro-computers possible.

   The term generation has also been used to distinguish the sophistication of operating system facilities (see below) and more recently has become embodied in terms like 'fourth generation language' and Japan's 'fifth generation research programme' where it impies something advanced.

22. Laver F.J.M. 'A User's View of A.D.P. Systems Design' in *The Computer Journal* Vol 7, 1964-5, p.93

23. Hardware is taken to mean the physical mechanism by which processing is achieved and software to mean a program of instructions. (NB. the spelling 'program' which is normal in technical circles is used throughout this thesis). This flexibility in combining the machine and its operating instructions is a natural implementation of the 'universal' machine where the hardware alone does not define its capabilities.

24. There are a number of techniques for this process such as compilation, assembly and interpretation. 'Translation' is used here to cover them all rather than in a specific technical sense.

25. Personal computing has arisen from the ability to reduce the circuitry for a computer to a size where it can comfortably fit on an individual desk. Some idea of the extent of this reduction in size can be seen from a comparison of a modern personal computer with ENIAC. The latter was 100 feet long, 3 feet deep and 10 feet high with the capacity for less than 2000 numeric

digits. A typical PC will be no more than 2 feet in each direction with potential storage of 640 kilobytes of data directly accessible and a further 20 megabytes or more on disc.

26. Mowshowitz A. 'The Conquest of Will', 1976, Addison-Wesley, Reading Mass, p. 36

27. Aleksander and Burnett (1983 op cit.) identify similar causal factors in explaining why Wiener's ideas were largely ignored in computer circles in the crucial period after World War II:-

> It was, perhaps, unfortunate that over-enthusiasm on the part of his disciples [encouraging the idea that he saw people as entirely replacable by machines] was mirrored by traits in Wiener's character which led him to savour his sudden elevation to the status of prophet with a certain ponderous relish ...... The main reason why, for a quarter of a century after the publication of 'Cybernetics', Wiener's proposal that mechanical intelligence might be investigated on 'bottom-up' principles went unheeded was the apparent impracticality of the undertaking. However intriguing the idea of direct comparisons between natural and artificial neural nets, it simply did not look like a workable proposition on either technical or economic grounds. (pp. 107 & 209)

28. Bowden B.V. (Ed.) 'Faster then Thought', 1953, Pitman, New York, p. 15

His intolerance was legendary in his own time with, in retrospect, amusing consequences.

> Babbage was intensely annoyed by the cries of street musicians, who, so he said, made it impossible for him to concentrate on his work. Instead of following the example of a fellow sufferer - Thomas Carlyle - who retreated to a sound-proof room, Babbage embarked on a life-long vendetta against them, and tried to have them prosecuted. This public-spirited action so enraged his contemporaries that jeering children followed him through the streets; drum and fife bands came miles out of their way to serenade him, and indignant citizens who had an hour or two to spare made a point of having a drink at some local hostelry, and then blowing trumpets and other instruments under his windows at all hours of day and night. (Bowden p. 15)

29. Lady Ada Lovelace, whose husband was the poet Lord Byron, has now been recognised in the naming of a new language commissioned by the Americal Department of Defence (ADA). Unfortunately her mathematical skills were not up to the task of saving her from large gambling losses.

30. Bowden B.V. 1953 op cit.

31. Randell B. 1982 op cit., p. 14

32. quoted in Bowden B.V. 1953 op cit., p. viii

33. It was used by von Neumann for other calculations possibly including some required for the development of the Atomic Bomb.

34. see Sklair L. 'Organised Knowledge', 1973, Paladin, St. Albans

35. Wilder R.L. 'Evolution of Mathematical Concepts', 1968, J. Wiley & Sons, New York, p. 207

36. Pinch T.J. and Bijker W.E. 'The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other' in *Social Studies of Science* Vol. 14 No. 4, Aug. 1984.

On a social constructivist approach to technology, see also Woolgar S. 'Why not a Sociology of Machines? The Case of Sociology and Artificial Intelligence' in *Sociology* Vol. 19 No. 4, Nov. 1985

37. see Mathias P. 'The First Industrial Nation', 1969, Menthuen, London

38. see Pollard S. 'The Genesis of Modern Management', 1968, Penguin, Harmondsworth

39. Flinn M.W. 'Origins of the Industrial Revolution', 1966, Longmans, London, p. 77

40. Mowshowitz A. 1976 op cit., pp. 1 & 2

41. Pollard S. 1968 op cit.

42. Wynne B. 'C.G. Barkla and the J Phenomenon: A Case Study in the Treatment of Deviance in Physics' in *Social Studies of Science* Vol. 6 No.'s 3 & 4, Sept. 1976. See chapter 4.

CHAPTER 6

THE DEVELOPMENT OF COMMERCIAL COMPUTER SYSTEMS

COMPUTER SYSTEMS AND THE PROBLEM OF COMPLEXITY

A Further Demonstration of the Limits of Positivism

The last chapter began to develop empirical support for the synthetic concept of technology by contrasting its interpretation of the historical development of computers with that offered by a positivist/causal analysis. The positivist view set historical events within a progressive sequence constructed retrospectively and with knowledge of the 'final' result, the computer. It employed without question contemporary categories and concepts to explain both the present and its derivation. The synthetic view explained the same events in terms of the indexical meanings of actions within the context of the institutional and social logics prevalent when they occured. As a result, the eventual development of the modern computer was seen to be a consequence of broad social changes rather than the independent development of science and technology. Hence, it was shown to be the relationships within which change occured, and the multiplicity of alternative courses they presented, which gave rise to the possibility of computers, the desire to create them, the concrete form they have taken, and the uses to which they are being put.

In this chapter, and the next, the synthetic concept of technology will be applied to changes occuring in contemporary computer technology. This chapter will look in particular at the methods used to develop commercial data processing systems. It will explain the nature of those systems and describe the process by which they are developed. This description will show that social and institutional resources are employed in shaping both the general form of the methods used and the specific design of particular systems. It will also show how these resources take concrete form through the actions of the individuals involved in the development process. Thus, it will be suggested, computer systems, and the programs (2) which are their main component, are not the consequence of an objective technical process but emerge from a social discourse. The second half of the chapter will then examine ongoing debates about the methods of systems development and how it should be managed. This will demonstrate that the epistemology underlying the development process is based on positivist principles through the application of mechanistic models from mathematics, engineering and management.

A recurrent theme in this chapter will be the difficulties currently being experienced in establishing development methods and managing the development process. It will be suggested that the explanation of these difficulties lies in a failure to recognise, or adequately account for, the social nature of the development process; in particular the complex and abstract nature of the reality being subjected to computer processing. This failure, it will be argued, results from the limitations of the positivist principles which underlie current methods and which are being exposed in this new arena.

The Value of Computers as an Empirical Subject (3)

Computer systems provide a fruitful subject for exposing the limitations of positivism because they embody features not associated with traditional technology. Although they are still based on the use of a machine, they process and output symbolic representations rather than concrete materials (4). Hence computers provide the same enhancements to human mental functions that other technology has provided for their physical functions. However, whilst the different parts of the physical body have limited purposes and capabilities which can be isolated from the whole, the brain, through its manipulation of symbols, can be adapted to many functions. Consequently, in trying to extend the capabilities of the brain, computers have reversed the tendency to specialisation inherent in other forms of modern technology. The computer as a machine (hardware), like the human body, is of little practical value in itself. Instead, it represents a potential which requires instructions to direct its operation. This is provided by programs (software) which are analogous to the brain within the hardware body.

Computer software operates at two main levels. The first, systems software, directly controls the physical operation of the machine. The design of modern machines typically creates an 'architecture' in which the software and the hardware are combined to achieve the necessary functionality, and in which, to some extent, they are interchangeable (5). To continue the physical analogy, therefore, this software is the equivalent of the unconscious and instinctive functions of the brain. The second type of software, applications software, directs the processing of specific data and will normally only be present when actually required. This is the level at which commercial data processing systems operate. This type of software is equivalent to the conscious brain which may engage in any number of different projects.

Some computers are designed for special purposes, for example process control in an oil refinery and rocket guidance systems. In such cases, the software will only have one function and there will be no effective distinction betwen the two levels. This chapter, however, is not concerned with such special-purpose applications or with the development of computer hardware. Rather, its focus is on the develoment of commercial data processing systems (6) in which the flexibility afforded by the general-purpose computer provides the ability to process large amounts of different types of data quickly. It is by discussing this example that the limitations of traditional mechanistic conceptions of technology will be exposed and the representation of systems development as an objective technical process challenged.

<u>The Nature of Commercial Computer Systems and Programs</u>

Before describing what a computer system is, and how it is developed, two points must be made about the nature of this description. Firstly, it must be recognised that what is being described is the commonly accepted understanding of systems and consequently, mechanistic concepts and terminology are used which will later be brought into question. The second point to be made is that methods and ideas about how systems should be developed are changing rapidly. No description can be true in all cases and that offered below is a generalisation which for some systems will already be out of date. This reflects the fact that during the time taken to prepare this thesis there have been significant changes in all areas of computer technology. For example, improvements in communications networks mean that many more systems are now being developed which involve direct interaction between the user and the system through the use of visual display units (VDUs). Personal computers have also brought about significant changes in computer awareness and the types of application for which computers can be used. Networking and personal computers have also both had a direct impact on the methods and tools used to develop systems. In such a rapidly developing situation any description can soon become dated. However, for the purposes of this thesis, the important factor is not the specific methods being described but the process of change through which they have evolved. In that context the trends indicated in the description below are more important than up-to-date detail.

Similarly, there are many different types of computer application and new areas are regularly being explored including those related to artificial intelligence which are discussed in the next chapter. In this respect also, therefore, the following description is a generalisation which is more appropriate to traditional systems development than some of the more recent types. Within these limitations, a commercial data processing system can most simply be described as a means of transforming data. Thus, typically, systems and programs are described in terms of their input and output, and the process by which the first is transformed into the second. These elements may be related sequentially or through an interactive process. Each may involve the use of files, that is collections of data stored in such a way that it can be used by the program. Examples of such transformations would be those from timesheets to wage-packets and from sales statistics to a marketing plan. It must be remembered that a full data processing system involves not only the processing performed by the computer, but the human processes which accompany it, such as the input of data and the use of the output. The discussion in this chapter, however, concentrates on the computer element of the system although it cannot ignore the influence on systems design arising from the need for it to interface with human actions.

A parallel for the typical computer system, then, is the type of clerical process which it might replace. Let us say, for example, that a clerk is passing invoices for payment. Input to this process would be the invoices presented for payment and its main output, an authority to make payment. The clerk would perform checks on each invoice; for example, that it was correctly calculated and that the goods to which it referred had been received. The latter check would involve reference to a file of orders and delivery details. The procedure would allow alternative actions according to the consequences of the checks. Thus, it would have to allow for invoices covering more than one order, or for which no order could be found. It would also have to involve appropriate courses of action where any of the checks failed, for example where the goods had not been received or an expected discount had not been allowed. Accepted invoices would be put in a file for payment and the others disposed of according to the condition which stopped payment.

A computer program would follow essentially the same sequence of events. It would read and check details of the invoice using a file of orders and goods received (7). It would follow a course of action appropriate to the results of its checks creating files for other programs such as one to print cheques. However, where the development of commercial computer systems seems to differ most from other technical practices is in the difficulty experienced in formulating and implementing basic principles to develop such programs. After forty years of experience it is still recognised that most systems take longer, and cost more, to develop than originally planned, and that they frequently do not perform in the expected way. They are also so complex in many cases that they are difficult to maintain and enhance. A fundamental reason for these difficulties is the extent and nature of the complexity involved which creates a new dimension to the interface between calculative systems and the empirical reality in which they operate. It is the failure of existing methods to resolve the contradictions of this confrontation which brings into question the conceptual basis offered by models of technological development and change based on positivist principles.

Within the positivist framework, complexity becomes significant when the sum of the different elements and relationships in a system create a totality which cannot easily be predicted or controlled. It takes on the new dimension when those elements prove elusive of definition. In developing computer systems these difficulties derive partly from the nature of the reality being modelled and partly from the exclusion of the human factor during the execution of a computer program. It is this aspect of programming which leads Naur to assert that program development taxes human ability to its limits (8). The reality of commercial computer systems is essentially a social world in which the knowledge required to perform a task is not limited to technical rules and not always simple to define (9). Human beings trained to do a new task come to it with taken-for-granted knowledge and skills. With basic job training, they can begin to perform that task on the assumption that they will recognise untaught or questionable situations and ask how they are to be dealt with. In time new principles and heuristics will be learned so that action in new situations can be determined without the need for specific rules.

Performance, therefore, results from generalised knowledge, specific instruction and experience. If a computer program is to function correctly in every case, however, it must be capable of dealing with any circumstance in a controlled way from its own resources from the first day of operation. In simple terms it must be told not to pay an invoice for £0.00 or that an address cannot be correct if it places York in Lancashire. To this extent, any computer system must be an 'expert system' in that it encapsulates the knowledge of an experienced human practitioner (10).

Meek (11) highlights the difficulties involved in fully specifying requirements when he attempts to develop a formal set of rules for the children's game of spotting car numbers with registration plates starting 1,2,3 etc. What initially seems to be a simple game is found to require rules to deal with a range of potential situations such as what to do with foreign and military vehicles, whether stationary ones can be included and what to do in the case of a vehicle which can be seen and whose number plate is known but is no longer readable. Many of the problems of managing program development and of poor performance in operation arise from a failure to identify and program for all the situations which may arise. Ince comments that:-

> Currently, a major weakness in the software development process is specification. We just don't seem to be very good at it. This is especially disastrous when you realise that because specification occurs early in a software project an undetected error can be catastrophic. (12)

According to Tsichritzis (13), it is problems of this nature that have led to the habitual failure of software projects to complete on time or to budget. The way in which systems are currently designed to achieve this feat is the next subject of this chapter.

THE SYSTEM DEVELOPMENT LIFE-CYCLE

Initiating a Development

Many discussions of the process of developing a computer system describe its life-cycle (14). The stages which they define and their nomenclature vary but all cover the same basic elements:-

a) Conception of a requirement

b) Analysis and clarification of the requirement

c) Design and specification of the system

d) Implementation

e) Operation and maintenance

These stages constitute the career of a development in which the possibilities of successive stages become progressively more limited by decisions made at the previous ones. The description of this career will show how it is constrained by the origins and social context of its development (15).

The first stage of the development life-cycle involves the conception of a requirement which the system is to meet. In many cases that requirement may be presented as a necessity so that, for example, a company selling goods will assume that it must have a way of obtaining payment for them. However systems are always developed within the context of a taken-for-granted world. Hence, the need for a payment system in a modern industrial society will assume a monetary economy. Simiarly, a marketing manager assumes the market economy and the profit principle in specifying a requirement for a market analysis system, the requirement for a production control system implies a specific notion of efficiency just as a project to land men on the moon implies a particular model of the universe and priorities for scientific research.

Weber recognised the role of such assumptions in the initiation of scientific work:-

> Today one usually speaks of science as "free from presuppositions." Is there such a thing? It depends upon what one understands thereby. All scientific work presupposes that the rules of logic and method are valid; these are the general foundations of our orientation to the world ...... (16)

However Weber acknowleges these presuppositions only at the conceptual stage, beyond which he defends the objectivity of science and insists on the necessity of preserving it. In the commercial context, a similar role is played by taken-for-granted assumptions which define what questions/requirements may legitimately be raised, which methods of investigating and answering are appropriate to them and the criteria to be applied in judging the results. Thus they constrain the statement of objectives, the possible methods of solution and the evaluation of their feasibility both technically and in terms of their benefit to the organisation.

The role of these assumptions in the initial definition of requirements is frequently ignored in studies of the development life-cycle (17). However, it is the contention of this chapter that it can only be understood fully if these factors are taken into account. Furthermore, if we apply the concept of technology developed in chapter 4, the operation of these assumptions cannot be understood simply by analysis at the social and institutional levels. It must also account for their specific and concrete implementation through the actions and interactions of individuals. Hence, although the requirement for a system may seem to be a natural consequence of circumstances, a closer look will usually show that its identification has involved a process of negotiation, occurring within the constraints of social and institutional logic, in which actions will be fashioned by the individual biographies and interests of those involved and their access to power. Negotiation and the exercise of power need not necessarily be overt. As Lukes (18) points out, the most potent exercise of power may not be in winning a debate but in stopping an issue being raised. Thus, those with the power to sanction developments may exclude some possibilities because it is known that they will not find favour. Even where a project is proposed, the way it is presented and justified may be designed to appeal to the known preferences of those with the power to sanction it. Thus, by the time that the second stage of development, analysis, begins, a number of decisions will have been made and possibilities excluded through the operation of taken-for-granted assumptions, and the intentional and powerful actions of individuals.

The Analysis Stage

The object of the analysis stage is to clarify the initial requirement by translating it into specific objectives whose achievement can be identified and measured (19). At the same time the feasibility of the objectives is assessed and the methods by which they can be achieved evaluated. This stage focuses and hardens the decisions made in the conceptual stage. In doing so, it establishes the principles on which the development will be based and by which it will be judged. The social factors operating at the conceptual stage continue to operate at this and all other levels. Hence the social and institutional logics which constrained conception of the requirement continue to define the context of development whilst, at the level of action, the working out of individual projects, the exercise of power and the process of negotiation also continues. As a consequence, those involved not only require technical knowledge and skills but must also be able to exercise them in a political environment. In Kindred's words:-

> No matter how thorough the preparation and technical training the systems people might have, they are valuable to their organisation only when they are thoroughly familiar with the personalities of its members, the strengths and weaknesses of its operations, and the informal as well as formal power structure at work in the organisation. (20)

Whilst these non-technical elements may be acknowledged, however, it is still normally assumed in formal descriptions of the development process that the analysis stage will be concluded with a clear and unambiguous description of the required system on which its subsequent development can be based (21). The analyst's role in providing this specification reflects the need to know in an uncertain world and to make an ambiguous world unambiguous. It also reflects the mechanistic assumption that such clarity is both possible and desirable. Its desirability, however, is frequently tempered by a recognition that it is rarely achieved. Weinberg suggests that:-

> Perhaps the most critical problem in systems analysis is that, *often, neither the user nor the systems analyst knows what is required or desirable.* (22 - author's emphasis)

Systems analysis is rarely taught, he suggests, because it is so difficult to simulate the political process of defining the problem. He discusses some techniques which may be applied in these early stages of development, but these largely ignore the difficulties which he has identified. Most writers do not even go this far in acknowledging these difficulties. Instead, by concentrating on the later stages of development, and assuming fully defined requirements, they ignore this early discourse.

Design and Implementation

The design stage translates the requirements specified by analysis into detailed plans for the system. Implementation turns this design into an operational system through such activities as writing programs and designing files. In both these stages, earlier decisions are further hardened as they take concrete form in the delivered system. The assumption that the analysis stage concludes with a clear specification means that these later stages are usually represented as entirely technical in their nature, the essence of technicality being that decisions are made on logical, rational and objective grounds.

The process of negotiation in these stages is more overt (23) but the congruity of the epistemological and cultural assumptions which guide those involved are masked by the assumption of technical objectivity. Hence as Mulkay notes in a general comment on technology:-

> It is important to recognise that the difficult task facing the sociologist here is that of providing an analysis of the *technical*, as opposed to what we might loosely call the *social* meaning of technology. Thus, it is fairly easy to show that the social meaning of television varies with and depends upon the social context in which it is employed. But it is much more difficult to show that what is to count as a 'working television set' is similarly context-dependent in any significant respect. (24 - author's emphasis)

The argument of this thesis, however is that these apparently technical stages of design and implementation are equally subject to non-technical criteria and to demonstrate this, two particular aspects of these stages will be considered in more detail; testing, and the criteria for assessing the quality of programs.

Testing is concerned with proving the correctness of the design and its implementation. It can occur at different levels of detail and for different purposes. One type of testing, for example, aims to ensure that the logic of each individual program meets its specification. Another checks that the programs interface with each other correctly, that is, that data output by one is in the format expected by another. Other tests check that the system as a whole performs the required business functions and that it it is acceptable to the people who will have to use and operate it. Each type of testing poses questions which require a decision by the tester.

An example will illustrate this. One type of test applied to individual programs is designed to ensure that they operate successfully on a range of different values. The implications of this type of check are illustrated by Van Tassel (25) who calculates that to test every possible combination of two numbers for an operation taking one thousandth of a second, would take 50 billion years (26). When it is realised that a system of any size will contain hundreds of such operations, the impracticality of fully testing programs, even on this one dimension, becomes apparent.

Testing the logic of a program creates similar difficulties. To appreciate the nature of such testing it must be understood that the flexibility of computer programs resides primarily in their facility for making decisions on the basis of the data being processed. Each decision will be a choice between two possible courses of action. However, as one decision after another is made, the resulting geometric increase in the number of alternative paths through the program's logic means that it may weave a very complex web. This problem is typified by chess playing programs which quickly run into difficulties if they try to evaluate every possible option more than a few moves in advance. Whilst theoretically it would be possible to test each route, in practice the time required would be prohibitive.

Because it is not possible to test every possible combination of logic paths and values which the program may encounter in its operation, a decision must be made as to how thorough the testing will be. Any testing uses resources and extends the time taken to complete the development. As we might expect, therefore, the positivist criterion of efficiency is invoked in the decision-making process in the form of a balance between the potential cost of the system failing in operation and the costs of different degrees of thoroughness in testing. As a result, a satellite controlling program or an aircraft navigation system is likely to receive more thorough testing than an accounting package. Even so, there can be no absolute certainty, except in the most trivial cases, that the system will not fail in some unforeseen circumstance. Testing then can only be based on a sample and must seek to prove principles rather than cases. As a result, it is possible for a program to run throughout its lifetime without exposing an error if the conditions which would cause it never occur. Hence, in words echoing Popper's concept of falsification (27), Wirth argues that:-

> Experimental testing of programs can be used to show the presence of errors but never to prove their absence. (28 - emphasised in original)

Once it is recognised that there is no realistic way of fully testing a program, what constitutes a 'working' program becomes a pragmatic decision based on an evaluation of the possibility of success and the consequences of failure. The nature of this evaluation is illustrated by the example of an expert system designed to offer a medical diagnosis for a set of physical symptoms. The system may not achieve a correct diagnosis in every case, nor even as often as the most successful medical experts, but if it is consistently more successful than the average medical practitioner, it will not be rejected because it is not totally accurate. Even so the value placed on its diagnoses will vary according to the circumstances of its use. For example, it would be given more weight when being compared with the conclusion of a medical student than with that of a consultant. Computer systems like any other form of technology, therefore, are not finally proved by the ingenuity or skill of their creation, or the 'validity' of the principles on which they are based, nor by the methods used to construct them, but by the pragmatic consequences of their use.

Even when the tester is satisfied that a program achieves the expected results or performs to an acceptable standard, other types of testing will be required to show that it meets its functional specification and is acceptable to the people who will use and operate it. Once again the criteria for these tests are pragmatic. To use an example from a different type of technology, a vehicle with a maximum speed of 5 m.p.h, fuel consumption of 10 gallons to the mile, a width of twenty feet and a weight of twenty tons is unlikely to fit most people's concept of a working motor car (29). In the same way, a computer system for airline reservations which accepts instructions from a remote terminal, records the reservation and prints a ticket back at the terminal may be meeting the output specification for its design. If it takes twenty minutes to do so it will not qualify as a working system by contemporary standards because the customer does not expect to have to wait that length of time.

These criteria will have been laid down in the analysis stage and will therefore have been subject to the social process described above. This will have involved the balancing of a number of factors such as cost, benefit, and time and resources available against the level of function and performance required. Hence defining a program as 'working' involves not only producing the required end result, but doing so according to criteria derived from the world in which it will be used. This world decides that aircraft crashes through incorrect computer navigation are less acceptable than a gas bill for £0.00. It operates with a concept of time which leads an airline customer to expect his booking to be confirmed in seconds rather than minutes and involves a notion of efficiency which determines what cost is acceptable in achieving these results. The definition of a system as 'working', therefore, involves socially derived considerations of both function and performance (30)

In the same way that the criterion applied in testing must be balanced, so we find that the evaluation of program quality involves the balancing of various factors. Chantler (31) lists the features of a quality program as:-

- accuracy - does what is required
- reliability - goes on doing it
- robustness - copes with exceptions
- efficiency - makes optimum use of machine resources
- usability - is easy to use and well documented
- maintainability - is easy to change
- readability - is easy to understand

Hibbard and Schumann (32) provide a similar list:-

- validity - with respect to its stated specifications
- integrity - under all possible conditions of usage
- efficiency - relative to the compexity of the task
- clarity - of both its structure and function

Hence they comment:-

> It has long been recognised that the ability to achieve a proper balance amongst such (not necessarily compatible) objectives depends primarily upon the way in which the programs are constructed. The degree of success is largely determined by the *techniques* employed during program development and by the *tools* used to support this process (where a programming language is merely the most traditional of these tools). (33 - author's emphasis)

Hence Van Tassel (34) argues that a program which optimises machine performance by using complex or obscure techniques is second best to one which achieves the required objectives whilst being easily understood. Thus, he is suggesting, there must be a balance between, in Chantler's terms, efficiency and maintainability. However the decision as to what that balance should be is made pragmatically according to the context of its development and proposed use.

The decisions made in constructing and testing programs may be portrayed by computer professionals as technical because the recognition and evaluation of these criteria is part of the everyday performance of the development function. However these examples illustrate that underlying their evaluation are pragmatic and social factors which are not technical in the accepted sense of being determined according to objective criteria. The cost/benefit analysis and measurements of efficiency which are part of the analysis and design stages of a commercial system may appear to be technically defined and give an objective evaluation of the proposal, but they are derived from the mechanistic principles of modern industrial societies. Thus the deciding factors are inherent in the social and institutional constraints in which the system has been developed and made real through the action of engaged individuals. They are not objective or independent parameters of the task of construction. Hence there is no absolute measure of a 'working' system and what appear to be technical criteria of evaluation are the distillation of a social process of negotiation, experiment and pragmatism.

THE ACADEMIC DEBATE

It might be expected that after forty years of use computer technology would have passed its 'adolescence' (35) and have established principles of system design. However, there is still considerable doubt as to what these principles are, or at least, how they can be applied. Hence, although many computer systems are in use, it is still common for the literature (academic, technical and popular), to bemoan the inability of developers to deliver systems on time, on budget and to specification (36). We have already noted the nature of computer technology and the new demands it places on its practitioners. We have also noted the tendency of those discussing it to underplay or ignore the social and abstract elements of the reality it deals with. Thus it is typically assumed that a clear specification of requirements should emerge from the analysis stage and that all subsequent decisions will be based solely on technical criteria.

In academic circles, therefore, the debate has concentrated largely on ways of resolving the consequences of complexity arising at the implementation stage of system development, especially during the writing of programs. Most of this discussion aims to define principles of construction derived from the existing models of the physical sciences but, as I have suggested, with mixed success. As a result the status of the new discipline of computer science remains unclear. Van der Linden, whilst accepting that there is some high quality software in existence concludes that:-

> Software writing is almost wholly a creative design activity. It is also a comparatively new discipline, which has yet to crystallise around solid principles. (37)

Buckle argues to the contrary that:-

> ...... design has become a more scientific process and less of an art ...... (38)

Dennis similarly argues that:-

> It is often asserted that software engineering is largely art and based very little on sound principle. Yet trends are visible and new ideas are developing that promise to substantially increase the role of theory and principle in the design and construction of software systems. (39)

Yourdon believes that the best programmers instinctively use the 'right' methods and the development of a programming discipline involves distilling principles from their work for the use of all (40). Hirst (41) describes this process of creating a discipline as the assimilation of experience into knowledge. This knowledge takes the form of central concepts and their relationship to each other, together with criteria of validity, and techniques and skills for further exploration. Wirth, a key figure in the development of a discipline of computer science, says of his own work:-

> My primary motivation is to introduce programming as the art or technique of constructing and formulating algorithms in a systematic manner, recognising that it is a discipline in its own right. (42)

However the development of a new discipline (43) cannot occur in a vacuum and in the case of computer science it is occurring within the context of mechanistic thinking in industrial societies. As a consequence, the methods proposed tend to be adaptations of its positivist principles. This is illustrated in the work of Abelson and Sussman at MIT which Durham suggests might be making some contribution to overcoming the difficulties of complexity.

> They try to teach their students strategies of design - technologies of thinking ...... Scheme [a programming language used in the course] is presented as a notation for abstract procedures, and only incidentally as a language which may be executed on computers. (44)

Abelson and Sussman suggest three main 'technologies of thinking'. The first is the use of 'black box' abstractions to break a problem into parts (45). This results in a description of the behaviour of the box, that is its input and consequent output, without any description of the transformation process itself. The second strategy is the establishment of conventional interfaces so that the boxes may be combined in a variety of ways. The last strategy is the use, and if necessary the development, of appropriate languages and tools to describe the concepts being used. However:-

> Their ideas on the design of large systems were cemented as strategies for the design of very complicated integrated circuits (46)

Hence Abelson and Sussman avoid the difficulties of analysis and specification by choosing an example in which the accurate statement of requirements is more readily achievable than in commercial systems. In practice they are teaching the conventional wisdom of the engineering model. They are not entirely unaware of social factors in this process; Durham paraphrases a comment by Sussman to the effect that:-

> Things don't get invented in a place ......
> They get invented by a culture. (47)

However there is no evidence that they question the cultural assumptions evident in their own teaching.

Academics tend to support one of two alternative mechanistic models. One is derived from engineering, as in the case of Abelson and Sussman, the other from mathematics, although the distinction is often blurred in the terminology used. The argument for the application of a mathematical model to programming is a natural development from the discussion of testing earlier in this chapter. As an alternative to current methods of testing, which always leave the possibility of error, those advocating the application of the mathematical model propose the use of formal methods of proof similar to those used in mathematics (48). This 'formalist' position does not necessarily imply that the required methods are to be found in existing mathematics. According to Grochla and Szyperski:-

> A growing number of companies are recognising the necessity to develop tools for the task of analyzing their information systems. However, the available mathematical theories for the most part do not appear to be an appropriate basis for the description and analysis of complex information systems. (49)

They see a need therefore to:-

> ...... develop new theoretical approaches and more powerful algorithms. (50)

Van der Linden summarises the position of one advocate of mathematical formalism, Hoare, with the assertion:-

> ...... that software engineering is the practice of basing programs on underlying theoretical, mathematical principles. Furthermore the use of mathematics should not be solely confined to the algorithms which a program embodies, but should be extended to the use of program proofs, logical program specification languages, and program verifiers. (51)

Linger et al (52) put the case rather differently. The proof of a program's correctness, they argue, is the personal satisfaction of the programmer. However this still requires the use of mathematical methods because that is the only kind of reasoned certainty possible.

Not all those involved in finding new techniques are as convinced as these writers of the value of the mathematical model. De Millo et al argue that attempts to apply the method of mathematical proof to programs misunderstands the nature of such proof which is:-

> ...... only one step in the direction of confidence. We believe that, in the end, it is a social process that determines whether mathematicians feel confident about a theorem - and we believe that, because no comparable social process can take place among program verifiers, program verification is bound to fail ...... The point is not that mathematicians make mistakes; that goes without saying. The point is that mathematicians' errors are corrected, not by formal symbolic logic, but by other mathematicians. (53)

In the end, they argue, theorems are accepted not so much because of their formal proof but because they have undergone a process of refinement by use in which they have been found to have practical value and consequently are internalised and used in subsequent work. Program verification by contrast is meant to be a one-time process.

If mathematical certainty is untenable however, De Millo et al suggest that the engineering approach may offer a better alternative because it embodies a more realistic notion of reliability which, above all, never demands perfection. The acceptibility of bridges and buildings is not determined by the technical content of the final product, but by factors such as economics, timescales and personalities.

Wirth has no doubts as to the applicability of the engineering model:-

> As in other engineering disciplines, the construction of a product - in this case, an algorithm - consists of a series of deliberations, investigations, and design decisions. (54)

But if the engineering model is a measure, then Morton is critical of the results to date:-

> ...... software in general shows all the signs of poor and inadequate engineering ...... there is very little software in the hands of users which has been built on the best available engineering principles. (55)

He does however accept the possibility of some long term benefit from this approach. Naur (56) is less sure. Attempts to apply the engineering model have so far proved disappointing, he argues, because they have not taken into account the unique character of the end-product. Van der Linden doubts that it can ever apply and comments:-

> But this gilded view ignores the fundamental nature of software, and the attributes which separate it from the world of the physical sciences.
>
> Software has such an incorporeal and insubstantial physical existence that the engineering stages associated with transforming a design into a solid physical reality simply do not apply. Indeed, it is counter-productive to try to impose this inappropriate schema in the attempt to "engineer" software.
>
> If software production is to be compared to engineering then the comparison must stop at the design stage - the completion of a prototype in engineering terms is the correct analogue for the completion of a program in computing terms.
>
> We do not gain by the fact that software production is completed so early in the traditional engineering cycle. On the contrary, we pay a heavy price. Instead of half-a-dozen or more steps of manageable intellectual proportions, we have telescoped all the complexity into just a couple of stages of labyrinthine difficulty ...... There is no such thing as a model of a program (except at the most trivial and abstract level) because the whole point about computer programming is that every last little detail has to be established. (57)

We can see, therefore, that even though the academic debate on principles of development concentrates on the 'technical' stages of design and implementation, it is far from over. In the literature, the consequences of complexity derived from the social nature of both the development process and its object are frequently avoided by the use of examples derived from machine oriented software closely related to the physical operation of the computer rather than the implementation of commercial data processing applications. Yet it is in this latter area that the unique nature and complexity of programming are most clearly demonstrated and the difficulties of applying the mathematical or engineering models are most apparent (58). Practitioners, however, cannot ignore these consequences even though they may not acknowledge their cause. Their approach, therefore, is less concerned with the principles involved and more with the practicialities of their work.

THE PRACTICAL APPROACH

Whilst the correct application of positivist principles to systems development is still being debated in academic circles, an examination of the practical steps taken will show that those principles are already established in the tools and methods used by practitioners. As new tools and methods are introduced, they are invariably found to reformulate the computer system development process in the image of one of the positivist models used in the development and management of other forms of technology. Indeed, a closer affinity to the practices of other disciplines is often heralded as the only way to master the problems being experienced. Hence Burns comments that:-

> For twenty years some members of the profession have endeavoured to introduce more scientific theories and better engineering practices to the art. The term *'Software Engineering'* was coined as long ago as 1968!
>
> The essence of Software Engineering is the use of systematic, structured ways to specify, design and implement systems, and to manage all these processes. (59 - author's emphasis)

The consequent application of mathematical and engineering concepts is illustrated by the principles currently applied to the practice of systems development and to its management.

Most of the ideas for new tools and methods in the design and implementation stages revolve around the concept of structure used by Burns which took its early form from the work of Dijkstra (60). The objective of structured techniques is to achieve clarity and control in complex situations. Its principal concept is the reduction of complex tasks to a series of more manageable ones with clearly defined interfaces so that each task can be developed independently. Subsequently these parts will be reassembled to create the whole structure whose characteristics are the sum total of those parts. Quite obviously this is a direct application of the positivist principle of wholes and the mechanistic concept used, for example, by Abelson and Sussman. The ideas of structured programming are now the accepted methodology of computer science to the extent that programming languages for schools are judged by their adherence to them (61) and home computer books apply them to the smallest machine.

For most authors (62), achieving a clear definition of the requirements for a system is treated as being synonymous with clarifying the parameters of a mathematical algorithm. In some cases what is called a discussion of programming is nothing but a mathematical debate on these lines. Emery defines an algorithm as:-

> ...... a set of unambiguous rules that define how a particular problem, or class of problem, can be solved in a finite sequence of steps. (63)

Maly and Hanson give a similar description and emphasise the role of algorithms in computer science:-

> Of central importance to computer science and, in fact, any essentially problem-solving disciplne is the notion of algorithms. The core concept, around which the entire book revolves, is the construction of algorithms in general and their computer representation in particular. (64)

An algorithm they define as:-

...... a procedure which always terminates after a finite number of steps for any allowable set of input quantities (if there are inputs). (65)

Higman is equally explicit:-

The most fundamental concept in computing is that of an algorithm. (66)

Wirth (67) goes so far as describe a program as essentially a mathematical statement of the form y=f(x) where y is the result of transforming x by applying the function/program f. It is no suprise then to find that his examples are concerned largely with the development of compilers for programming languages where the rules of transformation are rigorously defined.

However, the dominance of the algorithmic approach is not to be explained simply by its mathematical origins. Rather, as we saw in chapter 5, the technology emerged within a mechanistic environment whose principles were part of the symbolic universe of the principal actors involved and which became embedded in von Neumann's architecture for central processors (68). The influence of structured ideas is not easily escaped by the programmers, therefore. Not only does the hardware constrain them towards the algorithmic approach, but the tools they use, especially programming languages, often embody structured principles in their design. The role of such influences is illustrated by the name of one of the earliest programming languages, ALGOL, which is derived from the word algorithm. The same influences can be seen in the development of the language ADA (commissioned by the United States Department of Defence to be the main language for use in military contracts). These languages not only encourage a structured discipline, they deliberately make it difficult to write unstructured programs.

Commenting on the use of Pascal, another language designed to enforce structured ideas and one commonly used in university courses, Allan comments:-

> Part of the argument concerning Pascal is to do with Pascal *as a programmimg language*, however the more important part of the argument concerning Pascal is to do with Pascal *as an ideology* (almost a religion) which is trying to eradicate most other ideologies. (69 - author's emphasis)

He points out that there are other languages, many designed for specific types of programming, some of which are more suited to the work typically done in undergraduate courses. Why then he asks do so many academics concentrate on Pascal?

> The answer, as might be suspected, is mainly cultural, and has more to do with the self-esteem of certain academic computer scientists than with practicalities.
>
> To work out why the Peddlers are so keen on selling Pascal, we enter the sociology of professions. (70)

Thus he suggests that Pascal has been adopted because it expresses the structured ideas whose formality can be expressed in a form appropriate to the knowledge of a professional body, in this case academic computer scientists. This tendency to incorporate structured principles in the programmers' tools has become even more apparent with the introduction of 'fourth generation' programming languages. These are claimed to overcome some of the consequences of complex programming methods and in the process limit the facilities available to the programmer and encapsulate them in a relatively rigid structure (71).

Thus, although the arguments about the value of the mathematical and engineering models continue in academic literature, the analytical and mechanistic world-view from which they are derived is already shaping practical applications. So far the main emphasis has been on programming, however they have not proved to be the panacaea to all the problems being experienced. As a result the same ideas are now being applied to those stages in the development cycle which precede programming with an emphasis on achieving a correct and complete specification. The application is different but the principles and objectives are the same. This trend is typified by Yourdon (72) and Martin (73) whose work is directed at the practitioner rather than academics. Yourdon is quite specific about his assumptions on the political nature of computer development especially in the early stages:-

> Virtually everything in this book assumes that you are a rational manager; that you have rational programmers and analysts working for you; that you deal with rational users and customers; and that the environment in which you determine your schedules and manpower estimates is not only rational, but also friendly and supportive. (74)

Such an assumption is necessary if the formalisation of requirements which he describes is to be achieved. However, advising on the practical rather than the theoretical nature of the task, he is obliged to recognise some of its realities:-

> A project involving up to 100,000 lines of code is sufficiently complex that neither the analyst nor the user is likely to have a crystal-clear understanding of exactly what the system is supposed to do; and even if there *is* a clear understanding, the user is likely to change his mind about some of the requirements. (75)

As with programming, the structured philosophy has provided methods and exemplars for analysts as well as being the basis of their tools. At present the latter consist largely of assistance in gathering, ordering and presenting information. More recent ones also undertake some logic checking which applies the rules of structured analysis and thus forces the analyst to adopt them. However the promise made for these 'workbenches' in the not too distant future is that they will not only record information but suggest what information is needed and one recently launched product (76) provides a direct link to the implementation stage by generating the necessary programs as well.

The practical approach to complexity, therefore, quite clearly applies the principles of positivism and, as Ellul (77) suggests, these are slowly infiltrating into every aspect of the development process. They are to be found in the design of the hardware, in the tools used to develop systems, and in the principles applied to their design. However the application of positivist models does not end with the 'technical' process of systems development. It is also to be found in the methods used to manage the development process and some of the implications of that situation are considered in the final part of this chapter.

MANAGING THE DEVELOPMENT PROCESS

Discussions on the managment of computer systems development typically centre on how standard management models can be applied to that process and involve questions not only about which tools to use, but how to control and maximise the efficiency of those using them. Managers who use the systems developed by others often resent their reliance on the computer and the apparent anarchy of systems development whilst managers responsible for that development still struggle with the problems of complexity that it raises. Hence Weinwurm comments that:-

> For all practical purposes there are no generally accepted, generally available, or generally applicable guidelines or techniques on which a manager can rely (other than *ad hoc* experience of technical experts) in making cost or schedule estimates, in weighing the investment of increments of time and money against hoped-for improvements in performance or quality of the computer program end product, or in assessing cost-to-value after the fact. (78)

Although this was written fifteen years ago, the same sentiments are echoed today by Yourdon:-

> Indeed, one of the premises of this book is that conventional projects tend to be overbudget, behind schedule, expensive to develop, expensive to maintain, unreliable and unacceptable to users. (79)

The contributors to Weinwurm's book reflect a range of attitudes to this situation, from those who argue that the process of developing programs is not well understood, to those who believe control is simply a question of applying the same management techniques used in other engineering projects. Researchers have not been idle in seeking to show how computer development can be assimilated into existing and familiar management methods, not least because of the commercial advantage to be gained by anyone offering to do so. The formality and success of these methods is assumed although whether this is justified is open to question.

These attempts to formalise and structure the management of systems development are the subject of Kraft's (80) discussion of the emergence of programming as an occupation. His main theme concerns what he sees as the struggle by managers to gain control of the programming function. This control, he argues, is an end in itself and separate from the need to improve the quality of the programs produced. The drive to control, he suggests, is not unique to programming management but part of the basic management model applied in industrial societies. He makes a clear distinction therefore, between the technicality of programming and its control:-

> In *'Programmers and Managers'* I have described structured programming as many managers and programmers see it; I have suggested that managers use structured programming to de-skill and control their programmers. Yet, there is nothing inherent in the principles of structured programming - at least as put forward by people like Edsger Dijkstra, David Gries, and many others - which suggests that its developers are concerned with anything except making the writing of programs a more clear-headed and self-conscious undertaking than it presently is. (81)

Kraft compares programming with engineering occupations and, following Noble's lead, sees a number of parallels (82). The role of management in both occupations, he suggests, has been to look for and adopt ways to de-skill and control work. De-skilling is defined as:-

> ...... a deliberate effort to transform work made up of separate but interdependent tasks into a larger number of simpler, routine, and unrelated tasks. (83)

However, not only are programming and engineering both subject to de-skilling, they are also management's tool for de-skilling other work and therefore have both technical and managerial functions. The latter are to rearrange and redesign work tasks to increase management control and to simplify tasks so that they can be undertaken by less skilled workers (84). According to Kraft:-

> In this sense, computer programmers are the ultimate engineers. (85)

He believes that similarities in the development of engineering and programming education are critical and reflect the origins of the latter in electrical engineering whose traditions it has borrowed. Because much of Kraft's detailed discussion is based on the American education system, it must be treated with care in relation to Britain. However the comments on similarities between engineering and programming education could apply in both cases, their main point being the creation of two classes; the expert engineers/programmers and the semi-skilled technicians/coders.

In programming, Kraft identifies three main methods of de-skilling, the use of externally written packaged software, the use of structured programming, and changes in the organisation of work typified by the advent of Chief Programmer Teams. The principle of CPT's is that one expert programmer determines how each task is to be sub-divided and how its parts are to interface with each other so that they can be given, as self-contained units, to less skilled staff. Thus Kraft comments:-

> It is all here, quite plain and explicit: the major divisions between conceptual and routine tasks; a "Backup Programmer" who acts as both apprentice and potential replacement for the chief creative (and supervisory) worker; the modularization, i.e., fragmentation and standardization of work into routine segments. (86)

Once again he emphasises the motivation for this process:-

> The transformation of programming is not the result of technological imperatives inherent in the logic of programming or computing. Programming has changed because managers, concerned about profits, have set about systematically and carefully to change it. It has happened before. Similar attempts to routinize work have been made by managers of the most diverse workplaces. The common denominator has been the desire to substitute less skilled and therefore less expensive workers. (87)

Although Kraft provides a thought-provoking illustration of the nature of programming as an occupation, he raises a number of questions which his own analysis cannot answer convincingly. The reason lies almost entirely in his separation of the technical and management aspects of work. He does not ask why managers adopt the view of their function which he ascribes to them. Nor does he recognise that the same principles which underlie the management model are deeply embodied in society as a whole and consequently that the basis for the programmers' acceptance of their situation begins not in their technical training but in their assumption of the same cultural world as their managers.

His emphasis on the almost conspiratorial determination of managers to achieve control implies the consistent application of the same methods to all programmers, yet as Kraft himself notes:-

> But programming is not the same as assembly line work, at least not yet. Programming, even coding, is still primarily a mind-skill and there are few hard and fast rules of behaviour which managers can compare against an efficiency expert's model in order to check performance. (88)

He never asks why this should be so, nor does he acknowledge the significance of the fact that the same methods which he identifies as managements' tools for de-skilling have failed as yet to provide the solution to the difficulties of programming. In practice, we find that the adoption of structured techniques is not universal and Yourdon (89) suggests that resistance often comes from managers themselves for whom it creates new problems in terms of training, changeover costs and their staff's resistance to change.

Kraft's interpretation is based on the generalisation of a series of historical snapshots guided by a pre-formed notion of the nature of society. He alludes to the work of Braverman and Noble but essentially his analysis is in the standard Marxist tradition of Gendron (90) which maintains the independence of technology and concentrates criticisms on its application rather than the form it takes. Kraft implies that computers and programming, even structured programming, would have existed in the same form in other societies and still could. As a result, he constantly distinguishes between the technical benefits of structured techniques, which he considers appropriate to the task of programming, and their use by managers for political, that is non-technical purposes. The concept of technology constructed in this thesis, however, offers an alternative interpretation which correlates more closely with practice. It recognises that the cultural and epistemological worlds in which both the programmers and the managers operate is similar. The positivist principles of wholes and efficiency are natural to them both and there need be no conspiracy among managers to impose the structured concepts. In Noble's words:-

> From the outset, therefore, the engineer was at the service of capital, and, not suprisingly, its laws were to him as natural as the laws of science. (91)

This suggests that the factors which direct managers' choices and the reason programmers accept them, can both be explained by their common use of the same structural resources in understanding their work situation. Structured programming is not an objective technique turned by managers into a means of enforcing their authority, it is a natural application of the principles of mechanistic thinking by industrialised societies to new areas of knowledge, work and their management.

SUMMARY

In this chapter, a discussion of the methods used in developing commercial computer systems has provided a vehicle for developing the theme, introduced in chapter 3, that positivism has its limitations as a model for technological development. The empirical value of this subject, it was suggested, is its exposure of the positivist view, in its different forms, to a new dimension of complexity and abstraction. In the same way that Newton's mechanistic model of the natural world has been found inadequate at the frontiers of science, so positivist principles have been shown to be inadequate for this new type of technology.

This chapter has described three aspects of computer technology; the nature of commercial data processing systems and programs, the process by which they are developed, and current debates about the principles and methods which should apply to that process and its management. These descriptions establish that systems development is a social process and that the principles on which it is based are derived from positivism and take the form of mechanistic models of mathematics, engineering and managment. This provides the basis for the argument that the difficulties being experienced in establishing principles of systems development, and in its practice, are a consequence of the adoption of these models. Kraft's discussion of the management of programming served as one illustration of a positivist explanation and was contrasted with the alternative suggested by the synthetic concept of technology. The recent introduction of new methods and tools has aimed to overcome the consequent difficulties and some of the ideas they incorporate

may seem to be loosening the shackles of mechanistic thinking. However, in the next chapter the synthetic concept of technology will again be used to offer a different understanding of these changes.

NOTES FOR CHAPTER 6

1. See Chapter 2.

2. This American spelling has become the norm in technical literature and will be adopted here.

3. Although the physical analogy used in this section is questioned elsewhere in this thesis, its use is appropriate for describing the mechanistic form of contemporary computer technology.

4. There are various types of symbolic representation. The next chapter distinguishes between three; data, information and knowledge. For simplicity within this chapter the term 'data' has been used throughout.

5. See Buckle J.K. 'Managing Software Projects', 1977, MacDonald & Jane's, London.

   Some of the significant historical developments in systems software (operating systems) were discussed in the last chapter.

6. Commercial is used here as a generic term to include any form of administrative system, e.g. businesses and government organisations

7. The computer system requires additional checks. Its input is transcribed from the original form, in which it would be used by a clerk, thus providing an additional opportunity for error.

8. Naur P. 'Concise Survey of Computer Methods', 1974, Studentlitteratur, Lund.

   Not all systems represent the same degree of complexity of course but the source of difficulty is always the same. It might then be asked, why, if it is so problematic, are computers used at all. The answer lies in their speed and consistent accuracy and what these make possible. Most day to day commercial data processing involves the frequent repetition of a limited series of steps. The value of the computer in such circumstances is that it can quickly and invariably perform such tasks. However it has become a truism of system development that 20% of the effort goes in to providing for the normal course of events, and the other 80% into coping with exceptional situations. It is in this latter area that the implications of complexity become evident.

9. The indexical interpretation of bureaucratic rules has been explored, for example, by Cicourel A.V. 'The Social Organisation of Juvenile Justice', 1976, Heinemann, London

10. Expert systems are discussed in more detail in chapter 7.

11. Meek B. 'Why the Rules Have to be so Complex' in *Computer Weekly* 13/9/84

12. Ince D. 'Ultra-Reliable Software the Prize in a Testing Battle' in *Computer Weekly* 29/11/84, p. 23

13. Tsichritzis D. 'Project Management' in Bauer F.L. (Ed.) 'Software Engineering - An Advanced Course', 1975, Springer-Verlag, Berlin, p. 374

14. A more general description of these stages is to be found in Aspinall D. 'The Coming of Age of Computer Technology', 1971, University College of Swansea, Swansea

15. A similar description of human careers is given in Ashton D.N. 'Careers and Commitment: The Move from School to Work' in Field D. (Ed.) 'Social Psychology for Sociologists', 1974, Thomas Nelson & Sons, London

16. Weber M. 'Science as a Vocation', in Gerth H.H. & C. Wright Mills, 'From Max Weber', 1970, Routledge & Kegan Paul, London, p. 143

Kuhn recognises the role of presuppositions in science in his concept of paradigm; see Kuhn T.S. 'The Structure of Scientific Revolutions', 1970, Chicago University Press, Chicago

More recently a similar argument has become a key element of the 'Finalization' thesis of science where finalization is defined as:-

> ...... a process through which external goals for science become the guide-lines of the development of the scientific theory itself.

Bohme G. et al 'Finalization in Science' in *Social Science Information* No. 15, 1976, p. 307

17. The existence of presuppositions is recognised by management scientists who have devised 'brain-storming' as a technique for temporarily suspending their constraining effects. Its basis is that no idea, however outrageous it might seem, is excluded. De Bono's principle of lateral thinking has the same objective; see De Bono E. 'Lateral Thinking', 1970, Ward Lock, London

18. Lukes S.M. 'Power', 1968, Blackwell, Oxford

19. The currently popular term is 'deliverables'.

20. Kindred A.R. 'Data Systems and Management', 1980, Prentice-Hall, Englewood Cliffs N.J., p. 34.

See also Metzger P.W. 'Managing a Programming Project', 1973, Prentice-Hall, Englewood Cliffs N.J.

21. see Emery G. 'Elements of Computer Science', 1977, Pitman, London: Chantler A. 'Programming Techniques and Practice', 1981, NCC Publications, Manchester, pp. 21 & 31

22. Weinberg V. 'Structured Analysis, 1978, Yourdon Press, New York, p. 1

23. In a recent study which I undertook for my own employer, the extent to which development staff interact verbally as part of their work was considered sufficient to justify a recommendation that separate quiet areas be provided.

24. Mulkay M.J. 'Knowledge and Utility: Implications for the Sociology of Knowledge' in *Social Studies of Science* Vol 9/1, 1979, p. 80

25. Van Tassel D.L. 'Program Style, Design, Efficiency, Debugging and Testing', 1974, Prentice-Hall, Englewood Cliffs N.J.

26. An operation here is understood in its mathematical sense, e.g. an addition or subtraction. Van Tassel assumes that the numbers are held in 32 bit computer words which limits their size.

27. see Popper K.R 'Conjectures and Refutations', 1972, Routledge & Kegan Paul, London

28. Wirth N.E. 'Systematic Programming', 1973, Prentice-Hall, Englewood Cliffs N.J., p. 16

29. The vehicle described might be appropriate in other circumstances, for example, if it was an armoured fighting vehicle.

30. We must be aware of equating these requirements with fashion. They arise out of known possibilities, or ones which it might reasonbly be expected are possible. Hence, it may be fashionable to have a colour T.V. set, but the standard of performance expected is not a question of fashion.

31. Chantler A. 1981 op cit.

32. Hibbard P.G. & Schumann S.A. (Eds.) 'Constructing Quality Software', 1978, North Holland, Amsterdam

33. Ibid. p. v

34. Van Tassel D.L. 1974 op cit.

35. This term is used by Aspinall (Aspinall D. 1971 op cit.) for the period in the development of a new technology when its basic principles are being established.

36. This is not only true of computer projects of course. Others, for example space exploration, have also experienced difficulties, although not necessarily for the same reasons. However they are a timely reminder that we cannot take for granted the validity of the mechanistic model even in more traditional areas of technology.

37. Van der Linden P. 'Software Engineering - A Wish or a Promise?' in *Software* June 1983, p. 6

38. Buckle J.K. 1977 op cit., p. 1

39. Dennis J.B. 'The Design and Construction of software systems' in Bauer F.L. 1975 op cit., p. 12

40. Yourdon E. 'Managing the Structured Techniques', 1979, Yourdon Press, New York

Another interpretation might be that the 'best' programmers are simply those who have most successfully internalised the mechanistic methodology.

41. Hirst P.H. 'Liberal Education and the Nature of Knowledge' in Dearden R.F. et al (Eds.) 'Education and the Development of Reason', 1972, Routledge & Kegan Paul, London

42. Wirth N.E. 1973 op cit., p. xi

43. Wirth defines a discipline as methods independent of application.

44. Durham A. 'Adding a New Dialect to Design Languages' in *Computing The Magazine* 29/11/84, p. 26

45. The positivist concept of 'Problem' was discussed in chapter 3.

46. Durham A. 1984 op cit., p. 26

47. Ibid., p. 26

48. see Durham A. 'Countdown to the Formalist Approach' in *Computing* 31/5/84

Although this debate is essentially academic, it does intrude into the commercial world, eg, Sharpe describes what he calls the reductionist and constructivist schools within IBM, ie those supporting the engineering and mathematical models; see Sharpe R. 'A Clash of Deeply Held Opinions' in *Computing* 12/6/86

49. Grochla E. & Szyperski N. (Eds.) 'Information Systems and Organisational Structure', 1975, Walter de Gruyter, Berlin, p. 7

50. Ibid. p. 7

An algorithm consists of rules which define a transformation. This concept is discussed in more detail below.

51. Van der Linden P. 1983 op cit., p. 4

52. Linger R.C. et al 'Structured Programming', 1979, Addison-Wesley, Reading Mass

53. De Millo R.A. et al 'Social Processes and Proofs of Theorems and Programs' in *Communications of the Association of Computing Machinery* Vol. 5, May 1979, pp. 271 & 272

54. Wirth N.E. 1973 op cit. p. 125

55. Morton K.W. 'What the Software Engineer can do for the Computer User' in Bauer F.L. 1975 op cit., p. 4

56. Naur P. 1974 op cit.

57. Van der Linden P. 1983 op cit., p. 6

58. Much of the comment above is summed up in a book review by Russell Jones in Computing 19/6/86. The book is 'An Integrated Approach to Software Development' by R.J. Abbott published by Wiley-Interscience. Jones comments:-

> There's a dangerous confusion abroad in the minds of some sections of computer academia at the moment. They don't seem to understand the difference between software development and software engineering. This new book, aimed largely at computer science undergraduates, embodies that confusion. It thinks it's a book about software development. In fact, it's a book about software engineering.
>
> Semantics? No, I'm afraid not.
>
> Software engineering is, largely, concerned with developing computer systems that can, for the most

part, be pre-specified. Process control is a good example. So is compiler development.

And, certainly, software development can and should encompass software engineering techniques. But it also encompases the development of software that simply can't, for the most part, be pre-specified. The types of computer system most dp departments build fall into this category ...... [a problem] that books from and for academia such as this one - whatever their undoubted merits as software engineering tracts - overwhelmingly fail to come to terms with.

59. Burns D. 'Software Tools are Good for YOU', in *Software Engineering Tools and Methods* June 1986, NCC Publications Manchester, p. 3

60. see for example Dijkstra E. 'A Discipline of Programming', 1976, Prentice-Hall, Englewood Cliffs N.J.

61. Papert makes this case in his programming language LOGO developed specifically for school children, see Papert S. 'Mindstorms: Children, Computers and Powerful Ideas', 1981, Harvester Press, Brighton

62. e.g. Wegner P. 'Programming Languages, Information Structures and Machine Organisation', 1968, McGraw Hill, New York: Wirth N.E. 1973 op cit.: Van der Linden 1983 op cit.

63. Emery G. 1977 op cit., p.29. We have already seen this idea in Turing's 'universal machine'; see chapter 5.

64. Maly K. & Hanson A.R. 'Fundamentals of the Computing Sciences', 1978, Prentice-Hall, Englewood Cliffs N.J., p. xvi

65. Ibid. p. 23

66. Higman B. 'Foundation Course in Computer Science', 1975, Macdonald & Jane's, London, p. 1

67. Wirth N. 1973 op cit.

68. New alternatives such as parallel processors are being explored as the physical limitations of von Neumann's architecture are being reached, but the latter's serial approach still dominates.

69. Allan B. 'A Polemic on Pascal Peddling' in *Computerworld* 2/10/81, p. 18

70. Ibid., p. 19

71. They are not presented this way by those selling them. Their function is said to be removing the drudgery in programming in favour of its 'creative' aspects.

72. Yourdon E. 'Managing the System Life Cycle', 1982, Yourdon Press, New York

73. Martin J. 'Strategic Data-Planning Methodologies', 1982, Prentice-Hall, Englewood Cliffs N.J.

74. Yourdon E. 1982 op cit., p.xi

75. Ibid., p. 4

76. Information Engineering Facility marketed by Information Engineering Products, a company strongly associated with James Martin.

77. Ellul J. 'The Technological Society', 1965, Jonathan Cape, London

78. Weinwurm G.F. (Ed.) 'On the Management of Computer Programming', 1970, Petrocelli, New York, p. ix

79. Yourdon E. 1982 op cit., p. 3

80. Kraft P. 'Programmers and Managers', 1977, Springer-Verlag, New York

81. Ibid., p. 9

82. See the discussion of Noble in chapter 2.

83. Kraft P. 1977 op cit., p. 52

84. This is the process which Babbage describes as the division of labour; see chapter 3.

85. Kraft p. 1977 op cit., p. 20

86. Ibid., p. 60

87. Ibid., pp. 97 & 99

88. Ibid., p. 62

89. Yourdon E. 1979 op cit.

90. Gendron B. 'Technology and the Human Condition', 1977, St. Martin's Press, New York

91. Noble D.F. 'America by Design', 1977, Knopf, New York, p. 34

CHAPTER 7

MECHANISMS OF CHANGE

REINFORCING THE EMPIRICAL CASE

A central theme of this thesis has been the limitations inherent in positivism both as a means of understanding technological change and as a basis for the development of concrete technological applications. The basis for this claim was laid in chapter 3 which found positivism unable to provide a comprehensive conceptualisation of technology. Chapter 5 illustrated the consequences of those limitations for achieving an understanding of historical events, and the last chapter demonstrated their operation within a specific form of technological practice, the development of commercial computer systems. Computers, it was suggested, provide a particularly good demonstration of the argument because they give rise to a new dimension of complexity in technology, and it is in dealing with complexity that positivism is most vunerable. Even so, it was shown that the interpretation of the difficulties being experienced in developing systems, and the search for solutions to them, are still being constrained within the mechanistic paradigm derived from positivism.

The present chapter will reinforce and develop this argument in two ways. Firstly it will look in more detail at responses to the contradictions being experienced in systems development showing how new methods being introduced to cope with them reflect and are being constrained by mechanistic assumptions. The introduction of prototyping as a method of systems development will provide a specific focus for this discussion. The second part of the chapter will then concentrate more specifically on the question of complexity. It will argue that, in spite of existing difficulties, the rationalist momentum created by positivist logic is driving systems developers to explore increasingly complex realities, in particular in the area of artificial intelligence. The nature of artificial intelligence systems will therefore be explored to show how they expose even more directly the contradictions arising from the logic of positivist technology. As a consequence it will be argued that the limitations of positivism do not only bring into question its suitability for non-technical spheres of society, as Habermas and the Bergers argue, but also for areas which are 'technical'. In doing so it questions the technical/non-technical distinction and clarifies the nature of technicality. This discussion will lead, in the final chapter, to a consideration of the broader implications for technology, and for society in general, of the argument presented in this thesis.

The basis for the discussion in this chapter will be the synthetic concept of technology constructed in chapter 4. In adopting this concept we must remember that it does not offer concrete or immutable definitions or categories, but an intuitive understanding of the relationships through which technology changes. Thus it provides a resource for application in particular cases. Similarly, although this chapter differentiates and labels a number of responses to explain the changes which are taking place, and as a means of temporarily fixing the object of study, this is only a first step in the process of understanding. It is a pragmatic arrangement which reflects the pragmatism of technology itself. As Winograd and Flores argue:-

> In the act of design we bring forth the objects and regularities in the world of our concern. We are engaged in an activity of interpretation that creates both possibilities and blindness. As we work within the domain we have defined, we are blind to the context from which it was carved and open to the new possibilities it generates. (1)

Hence, the difficulty with the meanings of technology discussed in chapter 2, was not so much that they restricted their perspective to either its concrete or abstract dimensions, but that they closed themselves to the broader possibilities for synthesis and did not account adequately for the artificial and specific validity of their own cases. By contrast, although the construction of the synthetic concept of technology specified three levels of analysis, its potential is not limited by those categories. Instead it describes the generalised relationships which they characterise and the process of change which those relationships engender. Thus the development of knowledge becomes an iterative process in which an understanding of the parts, temporarily transfixed for the purpose, illuminates the whole in a way which can deepen the original understanding of the parts. The pragmatism of this approach acknowledges the need for the creation of artificial boundaries and categories but does not mistake their tenuous nature for an absolute reality. Instead it leaves the justification for their use to their success in achieving practical understanding.

RESPONSES TO CONTRADICTION

Contradiction in Action

Within the synthetic concept of technology, contradiction plays an important role in explaining the origins of change. It was identified at two points in the relationships through which change is transmitted; in action and in the institutional logic. The discussion in the last chapter showed some of the responses to the difficulties/contradictions which have resulted from current methods of systems development. In this chapter those responses will be examined further. For that purpose I propose to identify three general categories of response (2). The first category, which we may label repression, occurs when the circumstances giving rise to contradiction, and/or their consequences, are redefined so that they can be ignored. This was illustrated in two ways by the discussion of systems development. One example was the exclusion from most academic debate of the problem of achieving a clear definition of requirements from the early phases of the development cycle. Thus most texts concentrate on the design and implementation phases of systems development and use case studies which circumvent the problems of definition. The second example of repression was to be found in the argument that difficulties were being experienced not through any fault of the mechanistic logic of systems development, but because of its inadequate implementation. A typical consequence of this form of repression is the emergence of new methods whose justification is that they match the development process more nearly to the positivist-based engineering model (3).

However, the particular difficulties created by the potential for flexibility and the abstract nature of the raw material of computer systems has led, in some cases, to a recognition that existing models cannot be adopted without change. This has given rise to the second type of response, accommodation. Here the institutional logic is modified to take account of these special conditions, although not to the extent that the changes undermine the principles on which that logic is based (4). This type of response is illustrated by a shift in the interpretation of the development life-cycle which was described in the last chapter. Whereas traditionally the stages of the life-cycle have been followed sequentially, writers such as Yourdon (5) are now suggesting that situations arising at one stage may require reconsideration of decisions made at an earlier stage. Hence development will involve a series of iterations through the cycle. This approach makes some concessions to the difficulties experienced in achieving a clear and final definition of system requirements at the end of the analysis phase. Such accommodations may represent a permanent acceptance of the special nature of computer systems, but they may also suggest a temporary acknowledgement that current methods cannot match up to the mechanistic ideal.

The final type of response to contradiction is assimilation. In simple terms this may be seen as the converse of accommodation. It accepts the misfit between the paradigm and its subject but reacts by reshaping the subject to fit the expectations generated by the paradigm. The model for this process will be defined by the principals underlying the paradigm. Hence, in the case of computer systems, this may mean that where people find a system difficult to operate, the solution will be to redefine their role more mechanistically so that it follows the same strict rules as the computer system and takes no account of the context or the individuals involved. The discussion of expert systems later in this chapter will give some detailed illustrations of this type of response.

These different types of responses are not unique to technology. A scientist, for example, finding that experimental results do not fit with a theoretical position may respond in a number of ways. One way could be to redefine the theory to take account of the new results (accommodation), another to redesign the experiment to give satisfactory results according to the original theory (repression). A third response could be to redefine the results to conform with the original theory (assimilation). In practice the response might be a combination of these alternatives so that the experiment may be redesigned to confirm the original theory, and a separate theory constructed to account for the results of the original experiment. A causal explanation of such responses would regard them as the direct effect of the contradiction between the original theory and the experimental results. However, as the discussion of historical explanation in chapter 5 argued, this could not account for the origins of the contradiction, nor for the specific actions taken to resolve them. By identifying the experience of contradiction as a consequence of the pragmatic and indexical application of the paradigm of action, the synthetic concept of technology focuses attention on the institutional constraints on action and, using the categories of response identified above, will provide a means for understanding both the original contradiction and the form of its resolution.

Contradiction in Institutional Logic

So far the three types of response have been discussed in terms of contradictions in action. They can also be used to understand the response of institutional logic to its own, internal contradictions. One example of this type of contradiction results from the momentum generated by the positivist principle of control. To achieve control, it will be remembered (6), positivism assumes that all parameters in a process must be defined and their consequences for any input known. In positivist technology this finds expression in the creation of general rules and principles which constitute a specific, formally learned body of knowledge which may then be applied unchanged to specific cases. The ultimate expression of this concept of control is automation. The alternative, which we may call craft, relies on intuition, learning by experience and imitation, and the immediate and practical requirements of specific circumstances (7). This principle of control generates its own momentum for change within the logic of institutional technology, and its own contradictions. That momentum develops because the rationalisation of any process in order to achieve or maximise control will normally expose the 'irrationality' of related processes which in their turn become objects of rationalisation. The 'ripple' effect which this generates is similar to the image of knowledge throwing light on one area only to expose the larger area of darkness around it (8). The contradiction inherent in this process is derived from the assumption that overall control (or total knowledge) is ultimately desirable and attainable whereas, in practice, each stage of rationalisation exposes even more contradictions. The synthetic concept of technology, by contrast, recognises the pragmatic element in the process of technological change and explains it in terms of events and contextual factors directly relevant to the circumstances in which contradiction arises. It does not, therefore, have any developmental notion leading to an expectation of an ultimate and ideal state.

The technological imperative to rationalise and control is demonstrated by the process of industrialisation in Britain. The initial demand for increased production which stimulated the industrial revolution in the nineteenth century exposed the limitations of domestic labour and merchant capitalism. The resulting factory system exposed in its turn the irrationality of human labour, methods of management and the financial system on which industry was based. Rationalisation in these areas led to Taylorism, double-entry book-keeping and limited liability ownership. Even so, modern industrial organisations are still seeking ways to control the irrational elements of their environment (9). In the same way, initial difficulties in controlling computer programming have led to its rationalisation through the introduction of high-level languages, structured methods and fourth generation languages (10). These have facilitated progressive attempts to automate programming, but have highlighted in turn limitations which result from current practices in the earlier stages of the development life-cycle.

A new phase of rationalisation is now beginning, therefore, which aims to automate the analysis and design of systems. Initially the motive was to further rationalise the programming stage. Hence one product is described as follows:-

> It aims to replace much of that programmer intellect by computer power. Indeed, by next year it should be possible to generate entire programs in a language that the computer can understand from a system specification without human intervention. (11)

Already, however, rationalisation of these other phases is becoming an object in itself. The new tools being made available will correct logical errors in analysis (logical, that is, in terms of mechanistic rationality) and ultimately their developers see them automating further, for example by deciding who to question and what to ask them. The discussion of artificial intelligence below will show that this momentum is being carried even further, and where machines demonstrate the irrationality of humans as a source of mechanical power, artificial intelligence is demonstrating the irrationality of human mental processes. However, before proceeding to that discussion, we will examine one further example of the way in which responses to contradictions in systems development are fitted to the mechanistic model.

<u>Understanding Prototyping as a Response to Contradiction</u>

Prototyping in its traditional context, means the construction of a one-off model of a new product or process which has the same functionality as the intended end-result. Its purpose is to make possible the testing and modification of a design without the costs involved in the final product itself. Hence one proponent of the use of prototyping in computer systems development describes it as:-

> ...... similar to the well tried and tested
> engineering practice of building "prototypes"
> of proposed aeroplanes or ships, before
> moving to "final production" versions ......
> It mimics, almost exactly, the 'engineering'
> approach to designing a product ...... (12)

In the last chapter, however, Van der Linden was quoted as arguing that the engineering model cannot be applied to the development of computer systems. On the contrary, he argued, computer systems cannot be prototyped because it is impossible to achieve the full functionality of a program without constructing the finished product. Certainly, there is reason to question the validity of the analogy between prototyping in traditional engineering and the method given that name in systems development. The latter has two main forms. One, used in the analysis stage is typically found in the development of expert systems where the 'prototype' is used as a focus for the process of knowledge elicitation in which the reasoning and knowledge to be embedded in the system are identified and formalised.

The second form of prototyping has become established largely as a result of the increasing number of systems which use an on-line interface between the user and the system. Here it typically involves constructing a skeleton of that interface so that users and designers can manipulate the content and layout of screens, and the sequence in which they are presented. In both forms, therefore, prototyping introduces an interactive element to the development process. In the design stage, however, whilst to the user the prototype may seem to do everything that will be expected of the final system, much of the processing necessary in a production environment may not be present. For example validation on the input data may not be as stringent as the final system will require and the security necessary when updating production files may be missing. Consequently the prototype never attains the functionality which will make it a satisfactory means for testing a system and, as Van der Linden argued, cannot be equated with engineering prototypes.

Even so, the positivist pedigree of prototyping as a systems development method is quite clear, as is the perception of the 'problems' which its use is designed to overcome. In terms of the categories of response described above, it may be explained in a number of ways. One interpretation might be that it represents a repressive response to contradiction by ignoring the differences between computer systems and other forms of technology. Alternatively, the interactive development involved in prototyping might be said to recognise the difficulty of a user achieving a clear definition of complex requirements. Hence prototyping may be said to represent an accommodation to these difficulties. Yet again, by drawing users into the technical process of development, it may also be argued that people are being constrained to express their requirements in the context of the computer. Hence there may also be said to be an element of assimilation.

We are not limited to these separate alternatives, however, and an explanation may be constructed which has elements of all three. For example, prototyping could be seen as accommodating some of the special difficulties presented by computer systems and repressing others. Thus it offers a short term expedient for improving on the current situation and also moves nearer to the mechanistic ideal by drawing on engineering concepts and bringing non-technical users into that domain. Prototyping also illustrates, therefore, that whilst the three categories of response create possibilities for understanding technological innovation, they necessarily simplify in order to achieve this and cannot be attributed any absolute validity.

However, an understanding of prototyping, at this detailed and essentially concrete level, can only be a step towards a broader understanding of the processes of change which fostered it. According to the synthetic concept of technology, understanding is derived from a process which moves between the different levels of analysis. In chapter 4 technology was defined at a broad and abstract level and did not deal with any specific form or application. The description of system development in the last chapter narrowed that focus to one type of application and the discussion of prototyping above has narrowed it even further. The iterative concept of understanding now allows us to widen the focus once again. In doing so, we are not required to retain the categories used at the more detailed level, nor even to resurrect them if we revert to the same level of analysis later. Their value is entirely pragmatic and has been to simplify the subject sufficiently to allow an initial appreciation.

In widening the focus we will become increasingly aware of the complex nature of the process of change which has occurred and for which we must account. For example, in looking at the context in which prototyping has developed, we noted that it was related to improvements in communications hardware whereby on-line interaction has become the normal basis for design. Similarly, it is related to the conceptual changes which underlie developments in artificial intelligence, in the form of expert systems. In the same way, the introduction of other new techniques has occurred in conjunction with changes in different aspects of computer technology such as the availability of personal computers and the graphical capabilities they offer. Thus, as we look at the broader context of technological change, we identify a paradigm covering not only systems development but computer technology in its broadest sense. It is this paradigm which constrains developments in relatively diverse aspects of computing to directions of change in which they create requirements and possibilities for each other. If the focus was widened further, we would identify increasingly abstract and general paradigms within which the possibility of change in technology is itself constrained. Thus, ultimately, as in chapter 5, we find the explanation is grounded in the principles which guide the society in which the change occurs (13).

Thus, in the words of Winograd and Flores:-

> It is clear (and has been widely recognised) that one cannot understand a technology without having a *functional* understanding of how it is used. Furthermore, that understanding must incorporate a *holistic* view of the network of technologies and activities into which it fits, rather than

treating the technological devices in isolation. But this is still not enough. We can say that the word processor must be understood by virtue of the role it plays in communication, the distribution of information, and the accumulation of knowledge. But in doing so we take for granted the use of words like 'communication,' 'information,' and 'knowledge,' which themselves require close examination. (14 - authors' emphasis)

ARTIFICIAL INTELLIGENCE - THE ULTIMATE COMPLEXITY?

The Nature of Artificial Intelligence in Computers

The discussion in the last chapter illustrated the contradictions arising from the application of positivist rationality to the complex realities being addressed in commercial computer systems. Those contradictions it was argued are a consequence of the limitations imposed by positivist notions such as the relationship of a whole to its constitutent parts, causality and quantification. In the remainder of this chapter that argument will be reinforced by looking at what is perhaps the most complex computer application yet considered, artificial intelligence (15). In its present state of development AI does not provide the same practical evidence as systems development, but it has touched much more directly on the 'philosophical' questions raised by computer technology.

The term 'artificial intelligence' covers a number of fields of investigation and there is no clear agreement among its practitioners as to its exact scope. One field, which we may call robotics, is concerned with giving machines the equivalent of human senses and the 'intelligence' to interpret and respond to their input. The nature of the problem this presents is indicated by the current capabilities of industrial robots. If one of these machines is required to use, say, three different metal castings, these will have to be presented to it in the correct alignment and the right sequence for the process it is performing. The problem for artificial intelligence is to devise a means whereby the parts can be presented in an unsorted pile from which the robot selects the required casting whatever its orientation, even if it is partly hidden by others. This requires the kind of 'intelligence', therefore, which enables humans to visually identify objects (16). A second area of AI research, which may be labelled cognitive, seeks to replicate the human capacity for abstract reasoning, for example by correctly interpreting speech. This type of work has attracted most public attention through the increasing use of 'expert systems' and highly publicised projects such as the Strategic Defence Initiative (Star Wars). For the purposes of the discussion in this chapter, it is research into this cognitive form of AI which has most to offer.

Neither type of research necessarily assumes that the development of AI must copy exactly the methods of the human brain. For example, a test for the attainment of artificial intelligence devised by Turing, suggests that if a person, who is isolated from both a human respondent and a machine, cannot distinguish between them after interrogating them via a teletype, then the machine is demonstrating intelligence. This test makes no claim as to whether this is human intelligence, rather:-

> The underlying assumption of the test is that if a machine can *act* intelligent, then, for all intents and purposes, it *is* intelligent. (17 - author's emphasis)

Hence, the aim of expert systems is not necessarily to replicate human cognition, but to formalise representations of knowledge and methods of reasoning. In this way, it is assumed that ultimately they can capture the skills of human experts which can then be used without the presence of the expert (18). The logical conclusion of this idea is the creation of a cognitive 'shell' which embodies all forms of human reasoning and which may be applied to different bodies of knowledge as required. To date this degree of generality has proved elusive and most applications are specific to a particular knowledge domain and the style(s) of reasoning appropriate to it.

Work on the cognitive aspect of AI has, in recent years, taken two main directions (19). The ideas on which both are based originated in research establishments such as universities and these continue to dominate investigations into the fundamental and conceptual requirements of AI. The other direction of research has resulted from attempts to exploit AI in the commercial market and has concentrated on the development of expert systems. This second direction clearly illustrates the process whereby computers have been progressively applied to increasingly complex applications. In doing so they demonstrate the consequences of the rationalising momentum generated by the positivist logic of technology which was dicussed above. The hallmark of that logic in its application to computer systems is a tendency to reduce all relationships to its own form of mechanistic rationality and, where this is contradicted by other contingent factors in that relationship, to extend its rationality to those factors as well. Thus positivist principles become increasingly pervasive as each new area of 'irrationality' is revealed.

In their initial application computers continued two processes of rationalisation already under way. On the one hand they were used to control machinery and therefore removed some of the remaining potential for irrationality involved in human operation. On the other hand, they were applied to the largely repetitive and procedural aspects of clerical work thus continuing the process of mechanisation started by the use of calculating and tabulating machinery and creating the basis for automation (20). It is in this second sphere that computers have subsequently had most impact and in which the process of rationalisation is most clearly seen. One indication of that process is the changes which have occured in the way computer systems are described. The early use of computers was typically labelled 'data processing', reflecting their use in essentially procedural tasks. More recently, the term 'information processing' has been preferred. This is not simply a cosmetic or fashionable change, but reflects a difference in the use of computers whereby the concern has moved from the simple content or value of data to its function and interpretation. It emphasises the difference between data as a raw material to be transformed into a resource, and information as a resource in its own right. Whilst data processing constrains the representation of data into a computer processable form, which, as chapter 5 showed, is a development compatible with the positivist tendency to quantify, information processing also requires that the interpretation of data conforms to the requirements of computer processing. Although this change in emphasis could be interpreted as a consequence of the increasing sophistication of computers and those using them, it may also be argued that because information has an interpretive element which invokes a different dimension of human interaction, it represents a new level of complexity and rationalisation.

A new label now being applied to some forms of computer system is 'knowledge processing'. This has been heralded by an increasing interest in artificial intelligence and especially in expert systems. In knowledge based systems the process started by the transition from data to information goes one step further by requiring that formal expression is extended beyond the interpretation of data to the ways of thinking through which that interpretation is applied. As yet this type of application is not in the mainstream of commercial systems development, but already products are beginning to appear which apply the concepts and methods of expert systems to everyday systems rather than to stand-alone systems as is more commonly the case at present. An understanding of the differences between the three types of computer processing, data, information and knowledge, may be helped by an analogy with the differences between words, syntax and meaning, or between a dictionary, a grammar and a book (21). In each case the key point to recognise is that in progressing through these forms, content and value are of decreasing importance and more is represented by the statement in which they occur. Hence, while each word or item of data represents a discrete value, when it is expressed as information its function within the sentence or system becomes significant, and when it becomes knowledge, its context and relationship with the other elements adds a third dimension which is only meaningful in a broader context.

We can see, therefore, how these different forms of computer processing represent progressive stages in a process of rationalisation. Each moves the object of processing further from absolute to less precise and more abstract statements, trying none-the-less to encompass them entirely within a formal definition. An example of an expert system may help to clarify the nature of this process further, and for this purpose we may consider one developed to assist in the selection of equities suitable for investment by insurance companies (22). Like any expert system this one has two main components; a knowledge base containing the data and information to be processed, and an inference engine which is the formal statement of the reasoning to be applied to the knowledge base. In the equity system there are two major sources of knowledge; market statistics such as the current price of shares and their price/earnings ratio, and the opinions of the expert using the system on such matters as the quality of management in the company under consideration. The inference engine has been constructed by an expert in equity selection and a knowledge engineer whose function was to assist the expert to formalise the reasoning process involved. In this case the resulting system will be used by the expert and its function is not to replace him/her but to relieve some of the mundane calculation elements involved in equity selection and to bring them together with qualitative data and opinions to provide a consistent recommendation. This may always be overridden if there are other factors not taken into account by the system such as a possible take-over or the extent of current exposure to that particular market sector (23).

The Contradictions in Artificial Intelligence

In spite of the growing popularity of systems such as that described above, AI has its doubters and critics (24). One of the most persistent has been Hubert Dreyfus. In 1972, in 'What Computers Can't Do', he traced the faltering progress of AI research from its early grand claims to its (then) present state of knowledge. The difficulties being experienced at that time, he argued, resulted directly from the use of a mechanistic model of human intelligence. Even if it is possible to decompose knowledge into rules and logical relationships as the mechanistic model requires, he suggests:-

> ...... once these elements have been taken out of context and stripped of all significance it is not easy to give it back. The significance to be given to each logical element depends on other logical elements, so that in order to be recognised as forming patterns and ultimately forming objects and meaningful utterances each input must be related to other inputs by rules. But the elements are subject to several interpretations according to different rules and which rule to apply depends on the context. For a computer, however, the context itself can only be recognised according to a rule. (25)

Thus, it is being argued, a particular combination of rules and relationships only makes sense as a whole because it contains elements not derivable from any of the separate parts. Such a situation, as the discussion in chapter 3 showed, is not allowed for in mechanistic thinking. Hence, in a later book co-authored with his brother, Dreyfus suggests that the idea of human expertise being reduced to 'rules of thumb':-

> ...... does fundamental violence to the real nature of human intelligence and expertise [and] it is in this effort to create artificial intelligence that the nature, problems, and limits of mechanised reason are most clearly evident. (26)

To demonstrate the nature of this error in AI thinking a five stage model of the development of human expertise is constructed:-

1) NOVICE - the conscious application of context-free rules

2) ADVANCED BEGINNER - developing situational skills

3) COMPETENCE - the ability to select the critical features in a situation

4) PROFICIENCY - apparently instinctive performance through the ability to relate current situations to previously experienced ones

5) EXPERTISE - direct personal involvement in the situation

If these stages are applied to a car driver learning to change gear in order to slow down, then the first stage would simply involve learning the sequence of actions necessary. In the second stage these actions would be related to particular situations and by the third stage the driver would be competent to distinguish, for example, between circumstances where a gear change and an emergency braking stop were appropriate. In the fourth stage, proficiency, the choosing and performance of the required action would be done unconsciously on the basis of growing experience. We would expect most drivers, over a period of time, to achieve this stage. The transition to expertise, however, requires not just additional experience or knowledge, but a different quality of performance. The expert is no longer driving the car but is part of it in a way which is not allowed for in the duality implied by the term 'driving'. Hence, whilst the distinction of the first four stages, and the movement between them, is developmental, the difference between those stages and the last is discontinuous.

One view of this model might be that the Advanced Beginner and Proficiency stages are simply transitional. However, we will better understand the special nature of expertise if we emphasise the significance of the change in quality between the fourth and fifth stages (27). In examining these stages and the nature of this difference, we can also come to a better understanding of the nature of technicality. The first state, novice, is rule based and therefore entirely 'rational' in the mechanistic sense. The transition through advanced beginner to competence leads to the application of contextual knowledge, and therefore requires a more sophisticated rationality. This difference is not unlike that between data and information discussed above. Proficiency still applies the same form of rationality but its application is unconscious so that the driver may not be able to verbalise accurately the actions taken. Expertise however is arational, that is beyond rationality in the positivist sense. According to the Dreyfuses it occurs where:-

> ...... experience-based holistic recognition of similarity produces deep situational understanding ...... (28)

The process of developing expertise suggested by this model is the reverse of that described by Piaget and adopted by Habermas (29). For them intelligence starts with physical involvement as a child and progresses to the abstract reasoning of an adult. Expertise, however, requires a blurring of the distinction between self and context which is more typical of child-like action (30). AI research adopts the Piagetian model because it matches the way in which people reflect consciously (31). The alternative is branded as irrational, unscientific or mystical. The key to the Dreyfuses argument, however, is that rationality is not opposed to irrationality but to arationality which is the mode of expertise (32).

RESPONSES TO THE CONTRADICTIONS IN ARTIFICIAL INTELLIGENCE

In terms of the five-stage model, the early research into AI did not progress far beyond the novice stage. In effect, it adopted a behaviourist model which assumed that human intelligence consists of simple rule-based transformations whose output provides a measure of intelligence. It will be seen that this is similar to the mechanistic/engineering model based on the concept of algorithms and we will not be suprised that Turing conceived of both the 'universal' machine and the behaviourist definition of AI discussed above. In a second edition of 'What Computers Can't Do' in 1976 Dreyfus sees nothing in AI research since 1972 to question his original criticism of its fundamental principles. However, most AI workers, he suggests, have themselves come to recognise the over-simplicity of their earlier model.

> Looking back over the past ten years of AI research we might say that the basic point which has emerged is that *since intelligence must be situated it cannot be separated from the rest of human life.* (33 - author's emphasis)

In other words, the need for an element of contextual relevance has been recognised and AI researchers are now seeking to achieve a level of intelligent performance which is more advanced than novice and possibly up to the level of proficiency. In terms of the discussion above, we would interpret this change as being the consequence of contradictions arising from the unexpected complexity of the domain which has forced researchers to broaden the area of rationalisation in order to encompass the sources of those contradictions. Quite clearly, the realisation of its early shortcomings has not led to AI research being abandoned, so there has not been a revolutionary change. Rather AI workers have chosen to interpret their experience as an indication that the realisation of their objective will more difficult to achieve, and the model of intelligence they must use is more sophisticated than they had originally envisaged. Essentially, therefore, the difficulties and contradictions experienced so far have been interpreted as identifying the need for more complex sets of rules. It represents a move away from behaviourist concepts, through the recognition that what is essential to intelligence is not so much what is done but how it is done (34).

The result of this re-evaluation is illustrated in the work of David Hawkins on expert systems. The critical feature of expertise, he suggests, is not knowledge in the form of rules or formulae, but knowing when that knowledge applies. In terms of the Dreyfuses model, therefore, we might say that he recognises the situational skill which translates the novice into a competent or proficient performer. Thus he:-

> ...... does not build systems around a set of heuristic rules in no particular structure as in traditional systems. Instead he builds around a deep causal model of the domain in question, incorporating all the physical laws that determine its behaviour. (35)

He has applied his ideas to the development of an expert system for use in oil exploration. His system incorporates the theoretical models underlying the various disciplines involved in the decision to sink a well including those concerned with both its physical and economical aspects. These should identify potential wells which will be both physically feasible and economically viable. Each part of the model analyses its own data and then, in an effort to replicate the human process, the results are shared between the other models in a form of negotiated evaluation. Hawkins acknowledges the limitations of this approach. It relies on the degree to which the models replicate the real world which they are simulating, and, as they do not generate knowledge themselves, they have to be updated as new knowledge about those worlds is discovered from other sources. Hawkins is also aware of the extent to which his model assumes the oil exploration context and doubts whether any generalised model of expertise can be created.

In the terms of reponses to contradiction, this approach may be described as repressing the difficulties experienced in the practice of developing intelligent models. He has adjusted his own concept of expertise to account, as he sees it, for the contradictions arising from the early simplistic models. However his method is still firmly grounded in mechanistic principles and, in practice, he has simply widened the boundaries of the knowledge domain he is incorporating and moved one layer deeper into the mechanistic process. At the same time, there is an element of accommodation in Hawkins' admission that a general model of reasoning is an unlikely possibility.

Whilst Hawkins is involved in the practicalities of usable systems, others are researching at a more abstract level. One such researcher is Douglas Lenat whose early work resulted in some significant 'successes' in AI research (36). One program, for example, working from a set of concepts and heuristics, made a series of 'discoveries' in mathematics. However, whilst it could develop new concepts, it could not extend the heuristics being applied. Lenat therefore developed a new program which was able both to define new concepts and develop new heuristics. In Durham's words:-

> Its triumphs were many. It won the TCS war game, which is taken very seriously by America's top naval brass. One of its many original tactics was to blast out of the water any damaged and limping members of its own fleet. This ruthless stategem, outlawed in subsequent competitions, allowed the rest of Eurisko's fleet to cruise round at speed, unhampered by lame ducks.
>
> Another time, Eurisko stopped in the middle of the night and asked a question. It was allowed to be as inquisitive as it liked by day, but had been told expressly that programs do not get their programmers out of bed in the small hours. It turned out that Eurisko had decided it was no longer a mere program. It had redefined itself to be a person. (37)

In spite of these 'successes', Lenat found that there was also a point beyond which this program could not develop from within its own resources. In seeking to explain these limitations, he has acknowledged that some of the success of his earlier models was unintentionally built in, for example by the use of a mathematically based programming language. But he explains their real limitation as being a lack of commonsense. Even so, according to Durham:-

> Lenat has not abandoned his faith in machine learning. But the dream has faded somewhat. (38)

For the present, therefore, he has abandoned his earlier work in favour of a long term exercise to:-

...... equip a computer program with the 200,000 to 500,000 items of commonsense knowledge that he believes are possessed by every normal four-year-old. (39)

This idea is not new, in 1968 Minsky commented:-

I therefore feel that a machine will quite critically need to acquire the order of a hundred thousand elements of knowledge in order to behave with reasonable sensibility in ordinary situations. (40)

In 1983, Foder described Minsky's idea as 'embarrasingly like a Sears catalogue' (41). Sartre characterises it more graphically in his novel 'Nausea' where:-

...... the Autodidact, a pathetic and hopeless figure, devotes himself to the mastery of the whole of knowledge by reading alphabetically through a provincial library ...... (42)

If we were to label Lenat's response according to the three categories, we would say that, like Hawkins, it is repressive. Both have ignored the underlying reason for the contradictions experienced in earlier work and sought to match their efforts more closely to what they now perceive the correct model of human intelligence to be. Thus, although they have recognised the practical limitations of their original work, they have not recognised any fundamental incompatibility between intelligence/expertise and the proposition that it can be represented by computers. Consequently, the continued, if cautionary progress of their work leads to fears that the exaggerated claims made for AI in the 1970's will continue to be given credence and its products relied on to make crucial decisions.

While researchers are forced to acknowledge the limitations of their systems, the dangers may appear to be held at bay. However we should not believe that they can occur only in the future or that, as yet, we are undamaged by them. For example, a report on a sharp slide in share prices on the American stock exchange during 1986 puts the blame almost entirely on the use of computer systems.

> Computer generated selling of shares was estimated to account for almost 50% of the transactions ...... But it is believed that the effect of the computers involved was to exaggerate the underlying movement in the market, so that many shares were sold unecessarily ...... In particular, many systems are triggered by a drop in share price to instruct a dealer to sell, and he will often do so, even against his better nature, for fear of being caught out ...... Ian Reid, a director of Data Logic's finance division, said that although shares will often recover their price within a short time, some of the computer systems in the US do not have the intuition to see this. (43)

This example illustrates three consequences of the mechanistic approach in AI. Firstly, it reinforces the argument developed in chapter 6 that this approach is vulnerable to complexity and to the difficulties of identifying and properly accounting for every possible situation. Secondly, it demonstrates the typical repressive and rationalising reaction to contradiction which we have already seen in Hawkins and Lenat. This identifies the cause, and hence the basis for a solution, as being a lack of sophistication in the system rather than its unsuitability for what it is being used to do. Finally, it illustrates a typical human reaction to computer systems whereby people attribute less value to their own, possibly intuitive and 'expert', judgement than that of a computer. In other words, they are prepared to be assimilated into the computer system's rationality and take the corresponding opportunity to evade responsibility by 'obeying' it (44).

This last aspect is perhaps the most ominous tendency revealed by AI. Its logical conclusion is the assimilation of human intelligence rather than its replication. Specifically, AI tends to impose its limited model of intelligence onto humans so that they conform to the systems expectations. This is not only a feature of AI, it pervades all mechanistic thinking. However its application in AI adds a new dimension, the assimilation not only of human physicality (45) but mentality as well. As the Dreyfuses argue:-

> The assumption of calculative rationality implies that society can be improved by teaching children to think more analytically and by requiring adults who wish to advise us to justify their thoughts and actions in a supposedly rational manner. (46)

They illustrate the implications of this logic with research into the way pilot instructors teach novice pupils. The latter were told by their instructors to scan an aircraft's instruments in a particular order. The instructors assumed that they also followed this sequence, albeit unconsciously. However evidence of their eye-movements when flying showed that this was not the case and indeed there was no set order in which they scanned the instruments. The explanation offered by the Dreyfus's is that the order of scanning is intimately related to context and therefore to factors not articulated in the rules. Indeed, for the 'expert' pilot, the action is not rule governed and cannot be articulated.

Clearly if pilots were examined by a computer program, according to the 5-stage model of expertise it would fail the expert pilots. At best, therefore, human skill would be limited to the level of proficiency.

Another misunderstanding of the significance of the contradictions in AI is illustrated in a recent article about an expert system to value residential property for mortgage purposes. The authors have selected this area to gain experience in expert system methods. They recognise a 'fundamental problem' in eliciting an expert's knowledge and discuss the merits of various methods of doing so. It is acknowledged that:-

> Most of the knowledge inside an expert's head is experimental and uncertain, good guesswork rather than facts and rigour and so its extraction is problematic. (47)

However, as the article develops, it becomes clear that this lack of rigour is seen as a failing of the experts who:-

> ...... will often be hard pressed to describe their expertise in a systematic manner, let alone in a rationally structured form. (48)

Thus the authors conclude:-

> "Experts" it appears, tend to state their methods and subsequent conclusions in terms that are too abstract for effective computer analysis and resynthesis. Valuers are no different. They make complex decisions rapidly without exhaustively re-examining and restating each step in their reasoning process.
>
> Basic background knowledge (the current state of the housing market for instance), is assumed, and items of it combined so quickly that it is difficult to dissemble the process into its component parts. (49)

The article, therefore, describes a basic contradiction between the objective of expert systems and the authors' experience of developing one. Their conclusion, however, is not that the concept of expert systems and its representation of knowledge should be questioned, but that the methods used by the "experts" (note the very term is being questioned by the use of quotation marks) is somehow inadequate and irrational. They do not ask whether it should be possible to divide knowledge into 'component parts', only why it is proving so difficult.

Another researcher who has come to a very different conclusion as a result of his contradictory experiences is Terry Winograd. He has followed their logical implications to the point where he rejects his earlier belief in the possibility of AI. The impact of his criticism is reinforced by the significance of his earlier contribution to AI research which is indicated by one description of his seminal work as:-

> ...... probably the key synthesising document in the field, the cornerstone on which much of the AI edifice has been built. (50)

Winograd's work concerned the understanding of natural language. He was highly acclaimed for a program which appeared to solve problems in a micro-world of variously shaped blocks (51). However Winograd's current opinion is that this work:-

> ...... was based on an over-simple theory of meaning in which words and sentences refer literally to objects and properties and actions. Winograd now believes this approach excludes the possibility of intelligent behaviour. (52)

A recent book which Winograd co-authors (53), is described as launching:-

> ...... a methodical attack on ways of thinking that are common among people who work with computers. (54)

His change of direction follows a realisation that symbolic logic, on which these ways of thinking are based, assumes a context in which some factors are considered normal. However deep attempts to articulate these assumptions go, other assumptions are always required to explain them. This infinite regression makes it impossible to fully articulate the context of any statement in a form suitable for mechanistic processing (55). Language is only made possible therefore by shared, but unarticulated understandings.

Winograd's misgivings about the possibility of analysing natural language are not shared by everyone. One commercially available product is decribed as follows:-

> Intellect [the product] contains a dictionary of basic common words in the English language, plus a lexicon of words and phrases identified with a particular application plus grammatical rules of the English language. "These features", says Bramley [Managing Director of the company marketing 'Intellect'], "allow the user to converse with the computer as though it were another intelligent being". (56)

The same approach is reflected in the manufacturer's description of a systems analysis tool.

> ...... the IEW/WS doesn't store diagrams as pictures. Instead it stores the *meaning* of each diagram you create in a *knowledge base* we call the Encyclopaedia ...... The expert system in the IEW/WS uses hundreds of structured logic rules to check the correctness of your analysis. If you attempt to violate the rules of any of the common diagramming methods this tool offers, the IEW/WS immediately alerts you to the error. (57)

Even more bold is a brief article on another product which describes AI as leading:-

> ...... to systems which surpass human capabilities in reasoning, problem solving, sensor analysis and environmental control.

The product is described as:-

> ...... an Intelligent Knowledge Based System (IKBS), a computer system which effectively mirrors human expertise by applying the techniques of logical inference to a knowledge base. The knowledge base itself being an organised body of information, held within a computer memory, which holds information about how to carry out a task, just like the rules learned by a human through experience. (58)

The significance of these phrases is not simply what they imply about the products which they are describing, but that in the context of competitive marketing, they both indicate and reaffirm the underlying acceptance of the mechanistic model of human intelligence. They are further evidence of both the repression of the contradictions in AI research and the assimilation of human capacities to those which a computer system can match, and surpass.

SUMMARY

This chapter began by categorising responses to the contradictions experienced in applying mechanistic thinking to the development of commercial computer systems. It has argued that these categories, used within the framework of the synthetic concept of technology, provide a basis for understanding the direction and consequences of technological change. A discussion of prototyping was used to illustrate the use of these categories and potential complexity of responses in practice. However, whilst the three categories of response offered an initial appreciation, it was recognised that they had limitations. In particular, it was shown that a wider perspective will reveal parallel factors which contribute to the specific implementation of a change. Continually widening the focus of attention led to an appreciation of how these different factors are related to a common paradigm. Having developed this broader appreciation, reverting to the more detailed level of analysis was then seen to add a new depth of understanding in specific cases. The development of knowledge, therefore, has been represented as an iterative process whose results are as contingent as the subject to which it is applied.

In order to develop this analysis of responses to contradiction, and to reaffirm the arguments about complexity and the process of rationalisation inherent in positivist logic, another field of computer application, artificial intelligence, was examined. The basic contradiction between the objectives of AI and the nature of human intelligence were discussed and different responses to that contradiction identified. The most significant contributions

of this discussion are that it illustrates the consequences of the rationalising tendency of positivist logic, and highlights the potentially serious consequences of assimilation which result from the adaptation of human and social characteristics into a form suitable for mechanistic processing. Hence, I would suggest, the contradictions in artificial intelligence represent a significant addition to the critique of the dominance of mechanistic thinking in technology. The ecology debate is already making the case that the 'irrationality' of mechanistic thinking is in danger of destroying the balance of the earth's resources and hence threatening the physical environment. Artificial intelligence is now questioning the commonly accepted definition of what it is to be human (59). In Athanasiou's words:-

> Still, science gives us a troubled epistemology, and AI makes its weaknesses obvious ...... It is AI's task to extend the scientific project from the realm of 'nature' to the realm of 'mind'. And AI has yet to demonstrate that science's formal procedures are adequate to the task. (60)

The momentum created by technology, as we noted above, is to rationalise; it:-

> ...... succeeds through the conquest of disorder and the imposition of form. (61)

Artificial intelligence is taking this to its logical conclusion and we are experiencing a new dimension in the pervasiveness of positivism, a direct challenge to the intuitive element of human thinking. In the final chapter the broader implications of this tendency will be discussed.

NOTES FOR CHAPTER 7

1. Winograd T. & Flores F. 'Understanding Computers and Cognition', 1986, Ablex Publishing Corp., Norwood N.J., p. 178

2. A fourth response, which might be labelled revolutionary, is not discussed here. It represents the breakdown of the paradigm, a situation not yet relevant to computer technology

3. Currently popular phrases in marketing materials include 'software engineering' and 'information engineering'. Both are specifically intended to indicate a methodology which is closely related to the traditional engineering paradigm.

4. This would represent a revolutionary change.

5. see for example Yourdon E. 'Managing the Structured Techniques', 1979, Yourdon Press, New York

6. see Chapter 3.

7. see Sadler J. 'Ideologies of Art and Science in Medicine', in Krohn W et al (Eds.) 'The Dynamics of Science and Technology', 1978, D Reidel, Dordrecht.

   The difference between these modes of thinking is found in other social institutions. It is demonstrated, for example by a comparison of mercantilist and modern economic theory.

   > The leading feature of all these [mercantilist] writings was their practical concern with ways in which the policies of the state in matters involving trade, manufacture, agriculture and taxation could be so conducted as to augment the wealth of the sovereign and his subjects ...... Political economy acquired a distinctive naturalist methodology from its absorbtion in the Enlightenment - a methodology which, in the hands of a thinker like Adam Smith, provided a means of bringing together the partial insights of previous economic writers into a system of connected principles. (Winch D. 'The Emergence of Economics as a Science' in Cipolla M. (Ed.) 'Fontana Economic History of Europe: Vol 3', 1971, Fontana, London, pp. 514 & 516.)

8. This effect has already been encountered in the form of the 'technological fix' - see chapter 3.

9. Some of these were discussed in chapter 3.

10. This was dicussed in chapter 6

11. Cane A. 'Workbench which will kill coding drudgery' in *Financial Times* 5/6/86

12. quoted in Jones R. 'The Model Approach to New Designs' *Computing* 4/8/86, pp. 28-29

13. We even have to consider broader paradigms, such as industrialism, which are multi-national.

We might also like to speculate on the historical interpretation which will be given to prototyping in the future. A causal analysis will be likely to see it as part of a series of progressive changes in which computer technology attained traditional engineering methods. The synthetic approach however will see prototyping for what it is in current circumstances, a response to a present difficulty occurring within the constraints and possibilities of the existing institutional paradigm.

14. Winograd T. & Flores F. 1986 op cit., p. 6

15. The common abbreviation 'AI' will be used in the rest of this chapter.

16. Even this is a simple task for a human. It only requires recognition of three known and unvarying shapes. It does not take account, for example, of the human ability to recognise classes of objects such as tables and chairs.

17. Athanasiou T. 'Artificial Intelligence - Cleverly Disguised Politics' in Solomonides T. & Levidow L. (Eds.) 'Compulsive Technology - Computers as Culture', 1985, Free Association Books, London, p. 20.

The philosophical issues raised by AI are both numerous and complex. Some of the issues raised for sociology are discussed in more detail in Woolgar S. 'Why not a Sociology of Machines? The Case of Sociology and Artificial Intelligence' in *Sociology* Vol. 19 No. 4, Nov. 1985

18. It should be noted that the explanation of expert systems being offered here is very simplistic. It is sufficient to develop the argument being presented and any additional detail would almost certainly be out of date within a few months.

19. There are other directions not discussed in detail here. One is the development of hardware to provide for the enormous processing power required by AI. Changes in this area are seeking to overcome the limitations of the von Neumann architecture and are therefore looking more closely at the cybernetic ideas of Wiener. Similarly, the algorithmic languages suited to other forms of computer development are proving inadequate and new ones are being developed to express relationships rather than procedures.

20. The discussion of Marx in chapter 4 summarised his description of the process whereby mechanisation is a step towards automation.

21. Like many analogies, this one is superficially useful but begs rather too many questions if explored at any depth.

22. This system is the result of a collaborative venture by a number of insurance companies under the auspices of the British government's Alvey programme which aims to increase awareness and knowledge of the commercial potential of artificial intelligence.

23. This system reflects a growing accommodation with the difficulties of developing expert systems in which their role is being redefined as providing support for experts rather than replacing them.

24. It is not the object of this discussion to trace the history of AI or discuss the details of specific research efforts except where they illuminate points in the argument. However a number of books provide the necessary background, for example Dreyfus H.L. 'What Computers Can't Do - The Limits of Artificial Intelligence', 1979, Harper Colophon Books, London: Alty J.L. & Coombs M.J. 'Expert Systems: Concepts and Examples', 1984, NCC Publications, Manchester

25. Dreyfus H.L. 1979 op cit., p. 288

26. Dreyfus H.L. & Dreyfus S. 'Mind over Machine', 1986, The Free Press, New York, pp. xi-xiii

27. A similar type of difference exists between ordinary perception and the Buddhist concept of Nirvana. Capra notes the representation of such forms of knowledge in various Eastern philosophies which contrast the necessarily limiting nature of rational knowledge with the global, but undefinable and intuitive nature of transcendental knowledge.

28. Dreyfus H.L. & Dreyfus S. 1986 op cit., p. 32

29. We should not necessarily assume that all expertise is the result of a developmental process involving each stage of the Dreyfuses model. This may be true for some types of learning, but for others, such as the acquisition of a mother tongue, knowledge of rules will normally follow proficiency.

30. This does not mean that the child is an expert, simply that both share the same lack of inhibition inherent in rationality. It would be interesting, but beyond the scope of this discussion, to explore the implications of this notion of expertise for the definition of scizophrenia as a persistent inability to distinguish between self and environment, see for example Laing R.D. 'The Divided Self', 1969, Penguin, Harmondsworth.

31. That is people who have internalised the mechanistic model

32. To demonstrate the implications of this model, the Dreyfuses apply it to the comparative failure of the American economy when compared with that of Japan. Part of the explanation they suggest lies in the tendency of American executives to move between companies whilst the Japanese tend to be life-long employees. According to the five-stage model, the executive who moves between companies, depending on the extent to which his new work is in a similar field to the old, will normally be reduced, at best, to the level of proficiency. Only with time can immersion in the new company create conditions conducive to the attainment of expertise. In the same way, they suggest, over-reliance on rational techniques such as computer modelling and Discounted Cash Flow undervalue the intuition which marks the expert.

33. Dreyfus H.L. 1979 op cit., p. 62.

An illustration of the new approach of AI researchers is to be found in Michie's comment that:-

> Machine intelligence thus turns out to have the character more of biology than of physics. Although we must always strive for the great unifying and simplifying principles wherever they may be gained, we have to live with the fact that there is such a thing in science as irreducible complexity.

Michie D. 'On Machine Intelligence', 1986, Ellis Horwood, Chichester.

34. In terms of computer architecture, what has been brought into question is the pre-programmed algorithmic approach of von Neumann. To replace it researchers are now reassessing the possibilities of natural models such as neural nets; see the discussion of von Neumann and Wiener in Aleksander I. & Burnett P. 'Reinventing Man', 1983, Penguin, Harmondsworth.

35. Johnston R. 'Breaking the Rules' in *Expert Systems User* May 1986, p. 23

36. see Durham T. 'What Expert Systems Need to Become Street-Wise' in *Computing* 28/11/85

37. Ibid., p. 2

38. Ibid., p. 4

39. Ibid., p. 2.

    If this knowledge is restricted to facts acquired by a child in America with a particular social background and learning opportunities (which assume internalisation of the positivist concept of rationality), Lenat will still not overcome the problem of predisposition which he identified in his use of mathematically based programming languages.

40. quoted Dreyfus H.L. & Dreyfus S. 1986 op cit., p. 68

41. Ibid., p. 69

42. Danto A.C. 'Sartre', 1975, Fontana, Glasgow, p. 15

43. Garrett A. 'Technology led Wall Street to Drop Prices' in *Computing* 18/9/86

44. The same social process is at work here as that which leads advertisers to use people in white coats to imply the scientific validity of their products.

45. For example by making their speed of work match that of a production line - see Beynon H. 'Working for Ford', 1973, Penguin, Harmondsworth.

46. Dreyfus H.L. & Dreyfue S. 1986 op cit., p. 193

47. Gronow S. & Scott I. 'Learning to Place a Value on Knowledge' in *Expert Systems User* Aug. 1986, p. 10

48. Ibid., p. 11

49. Ibid., p. 12

50. Malik R. 'What is Japan's Fifth Generation Project Really About?' in *Computer Talk* 11/6/85, p. 6

51. The concept of micro-world was developed by Seymour Papert; see 'Mindstorms: Children, Computers, and Powerful Ideas', 1981, Harvester Books, Brighton.

It is a fundamental concept of the computer language LOGO designed by Papert for developing logical skills in children and shows one of the ways in which a pervasive assimilation to mechanistic thinking can be achieved.

52. Durham T. 'Language through the Looking Glass' in *Computing* 10/7/86, p. 30

53. Winograd T. & Flores F. 1986 op cit.

54. Durham T. 10/7/86 op cit., p. 30

55. A similar problem was identified in causal explanations of historical events - see chapter 5.

56. Jones R. 'A Natural Approach to Interfacing' in Computing 12/6/86, p. 14

57. Advertising material for Information Engineering Workbench marketed by Arthur Young

58. Description of a product called Nconf in INTERCASE, Issue 6, Summer 1986 (advertising material)

59. This statement is not meant to imply that this definition is inviolate. What is at issue is whether the autonomous logic of technology is the correct medium through which it should be changed.

60. Athanasiou T. 1985 op cit., pp. 23 & 24

61. Winner L. 'Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought', 1977, MIT Press, Cambridge Mass., p. 75

CHAPTER 8

CONCLUSIONS AND FURTHER DIRECTIONS FOR RESEARCH

THE PROBLEM OF 'TECHNOLOGY' REVISITED

The Problem

The purpose of original project from which this thesis is derived was to explore the development of knowledge about computer technology and its use. This work was halted and redirected by difficulties with the methodological possibilities available to it. At the practical level it suffered from a lack of facilities for collecting data on such topics as the educational background and professional training of computer staff. This led to a reconsideration of the available resources and thence to the adoption of expert participation as the principal research method. This not only overcame the original difficulty but also offered the opportunity to explore an unusual perspective in sociological studies. Furthermore, it brought into focus the second methodological difficulty of the original project, the lack of an adequate definition of technology. This difficulty had emerged from background reading on organisations and their uses of technology. Attempts to resolve it in order to provide a framework for analysis by expert participation quickly showed that the problem was not simply a result of the variations in emphasis found in different uses of 'technology', but arose from inconsistencies and conflicts which could not be resolved within any existing conceptual framework. As a result, the starting point of the thesis as it has now been developed became the resolution of this difficulty through the reconceptualisation of technology in a way which could resolve these contradictions (1).

This process of reconceptualisation has developed in two main phases. In the first phase, the nature of the problem of definition described above was demonstrated and was seen to reveal a fundamental schism between uses of 'technology' based on positivist principles, which typically emphasised its concrete aspects, and other uses based on non-positivist principles which typically emphasised its abstract characteristics. These alternative conceptualisations provided the main avenues of exploration in the search for a new concept of technology which could synthesise their differing orientations and thus encompass all the facets identified by the many other uses of the term. Positivism was found not to have that potential, but a new conceptualisation derived from a selective reading of various non-positivist writers was thought to provide the necessary synthesis. This gave rise to the two main themes which were developed in the second phase of the thesis; one concerning the limitations of positivism as a means of expressing complex relationships and consequently as an appropriate model for technology, and the other, the greater viability of the concept of technology constructed in this thesis. The empirical demonstration of the new concept was provided by a discussion of selected aspects of computer technology. These showed how both past and present technological developments can be re-interpreted in a way which achieves a deeper understanding of the process of technological change; its conditions and consequences.

In this final chapter these arguments and the evidence to support them will be reassessed in terms of their own validity and that of the research methodology from which they have emerged. Like the computer systems it has discussed, this thesis has had a career circumscribed by the conditions of its development and leading, through a series of decisions, to its present form (2). As a first step in this evaluation, therefore, the arguments and evidence of the thesis will be restated and some consequences of this career path identified in terms of the questions it has left outstanding. This reassessment will focus in particular on the question of whether there is any reason to believe that the results of exploring the limited empirical domain of computer technology are anything but the consequence of a special case which has been exaggerated by the use of expert participation as the principal research method. Consequently it will also ask why meanings of 'technology' grounded in positivist principles still dominate everyday and formal uses of the term when the case against them is apparently so strong. Finally, on the basis of this discussion, some further directions for research will be identified.

The Development of a Solution

Faced with the problem that meanings given to 'technology' are so variable, the search for an adequate conceptualisation began with a survey representing its existing use in formal and academic studies. Although not comprehensive, this survey demonstrated the variety of meanings acquired by 'technology' and the tendency of each to emphasise either its concrete or abstract facets. This identified both the scope which the new concept would have to encompass and the need for a synthesis of the two basic orientations. It was an examination of the potential of the concepts underlying these orientations, in the form of positivist and non-positivist principles, which provided a starting point in the search for that synthesis.

As might be expected at this early stage in the career of the thesis, a number of decisions were taken which fundamentally defined its scope and direction. One question raised by these decisions is whether the survey undertaken to establish the problem of definition was truly 'representative' of the meanings ascribed to technology and consequently, whether it excluded a use of 'technology' which already met the criteria specified for the new concept. In view of the pervasive use of the term 'technology', it is perhaps unreasonable to expect a definitive answer to this question. It must also be remembered that the principal object of the survey was to demonstrate the problem of variability and contradiction for which purpose its sample was clearly sufficient. However the question raised here does draw attention to the growing sophistication of discussions of technology since that survey was completed. As a result the problem addressed by this thesis may not appear as novel as it was when the work began and one possible direction for further research would be to relate its conclusions to these more recent uses and meanings of 'technology'. Even so the issues it raises remain critical and essentially unresolved in terms of their broader social consequences.

A second question raised by this first phase of the thesis concerns the adequacy of the positivist/non-positivist dichotomy as the principal means of directing the search for a new concept of technology. The pragmatic basis of such categories has been discussed elsewhere but its consequences are no more keenly illustrated than in this case. The question which arises, therefore, is not about the absolute validity of the categories, rather it concerns the value of this distinction for furthering our understanding of technology. As a result, any judgement must not be made on the basis of the decision to use these categories but on the evidence of their success in developing that understanding.

In pursuing the directions indicated by the dichotomy between positivist and non-positivist principles, the next stage of the thesis was to examine the possibility that the former could provide the basis for a new concept of technology. Those principles were found to consist of a number of mutually supporting ideas predicated on the assumption that any whole must consist only of the aggregate of its parts to which it can be reduced and from which it can be reconstructed. This assumes in turn that each part, and the relationships which they share, can be precisely and discretely defined. These ideas are the basis for particular notions of efficiency, rationality and control, and encourage action based on analysis and quantification. It was argued, however, that this model of reality has significant limitations in dealing with some types of complexity and the relationships to which they give rise. As it stands, it cannot embrace some features of technology identified by those writers who have concentrated on its abstract rather than concrete aspects. Furthermore, because the principles of positivism are assumed to be the only measure of scientific validity, they exclude the possibility of integration with other perspectives to broaden their application and so account for the facets of technology they now exclude.

In terms of the long and complex debate on positivism and its various implementations, this discussion represented a limited exploration of the subject confined essentially to the immediate need to construct a concept of technology. It therefore highlighted two aspects of positivism which played a key role in the subsequent explanation of developments in computer technology; a tendency to progressive rationalisation and the possibility of contradiction resulting from attempts to resolve complexity. The adequacy of this treatment of positivism must be judged on the understanding which has been achieved by that explanation. At the same time it leaves open the possibility of extending the case by a more thorough analysis of positivism at the theoretical level.

The consequence of rejecting positivism as a basis for a new concept of technology was that the search moved on to an examination of non-positivist principles. In this context, the term non-positivst was taken to embrace a range of theoretical positions rather then a single coherent view. The object of examining them was not to comment in detail on the potential of their individual contributions to a new concept of technology. Instead, the work of a number of writers was used selectively to construct an independent concept to meet the specific objectives of this project. The initial grounding for that concept was found in the work of Marx with its implicit assertion that technology cannot be treated as a separate parameter of the social equation but must be seen as an integral part of a dynamic process in which it is both defined and defining. The key to understanding technology was shown to be the changes mediated through that dual relationship which therefore provides a medium in which to synthesise the concreteness of technology in action and its abstract presence within the social whole. However, there are difficulties with this concept of technology as it is derived directly from Marx. In essence these are the result of his failure to fully escape the positivist framework. The consequences of applying his ideas without recognising these limitations were illustrated by reference to the work of Althusser and Sumner. On the other hand, a failure to retain the integrity of his fundamental insight into the relationship between technology and society was seen to result in new dichotomies such as that between work and social interaction created by Habermas.

The means to overcome the dificulties in Marx's work were derived from an examination of three other writers. Sartre and Giddens were used to explore further the duality of the relationship between action and institutions with an emphasis on the part played by individual actions. This was balanced by the work of Foucault which minimises the role of individual action through the significance it assigns to autonomous institutional development and the consequent constraints on people to act in certain ways. The various ideas and possibilities identified in the work of these different authors was then used to reconceptualise technology in a way which would meet the need for a synthetic and comprehensive concept identified in the first part of the thesis.

The concept which emerged did not provide a static definition of technology; rather it was described in terms of the relationships through which it develops and changes. In this way, technology as an abstract phenomenon was shown to reside in the rules and resources which make technological action possible. The constitution of those rules and resources was shown to be modified as a result of experience in applying them to concrete situations. Thus, it was argued, neither the abstract nor the concrete aspects of technology could fully define the multiplicity embodied in this relationship, nor embrace all its possibilities. Consequently, technology could only be understood through an intuitive understanding of this dual relationship and through an iterative process of focusing and refocusing at different levels of detail in order to use knowledge gained at one level to enlighten the others. The synthetic concept of technology, therefore, was essentially a pragmatic construction, concerned with understanding and not attempting a precise definition which it did not accept as being possible on a global scale. Hence the value of the concept could only be demonstrated finally through its use. This would indicate the possibilities it had created and any limitations it imposed.

The development of this concept raises two related questions, the validity of the concept itself and the adequacy of the method used to develop it. The method is once again grounded in the pragmatic approach inherent in this thesis. It relies on an intuitive understanding of technology derived from expert participation to draw on the work of others for ideas which can be incorporated into the new concept. This single-minded approach, as in the examination of positivsm, has no reverence for the complexity of the original work nor for the integrity of the context in which its ideas are expressed. The selection of the work examined is itself a consequence of the circumstances in which the thesis has been developed, for example the scope of my undergraduate course. The result is not, therefore, presented as a detailed analysis or critique of non-positivist principles but as a working hypothesis, the validity of which must be determined by its empirical usefulness. It leaves open the question of the relationship of the new concept to the issues raised and the resolutions offered by its sources. The resolution of this question and a similar examination of other non-positivist theorists both represent directions for further research.

To demonstrate and test the utility of the new concept of technology empirically, it was applied to three different aspects of computer technology. As a first step in this process two interpretations of the historical development of computers were contrasted; one imputed from the synthetic concept of technology and the other based on the positivist principle of causal analysis. This comparison demonstrated the value of the synthetic view which portrayed technology in the context of a complex social whole whose integrity was not compromised by the need to fit any developmental assumptions. In particular it exposed the inadequacy of interpretations of history which assume the social context of the interpreter rather than that in which the events ocurred and which see the present as an inevitable consequence of a series of past events. It also showed the value of the concept of discontinuity derived from Foucault and implied, but not fully implemented, in Marx's concept of revolutionary change. The synthetic interpretation emphasised, therefore, the pragmatic nature of technological change and the integrity of the social whole which enabled it to develop a more comprehensive and flexible understanding of the past.

The advantages of the synthetic concept for historical understanding were also seen to apply to the interpretation of changes in contemporary methods of developing commercial computer systems. The process of developing a system, it was suggested, is typically taken to consist of the application of objective, technical principles in pursuit of a fully defined requirement with known consequences. It was shown, however, that in practice, each stage of a development entails a socially constrained process of negotiation and decision-making in which its final outcome is the fruit of the progressively limited possibilities this makes available. Furthermore, far from being the predictable technical process which the mechanistic model assumes, it was seen that difficulties were being encountered in controlling both the development process and its results. In the technical literature these were typically being explained as the consequences of the complexity of computer systems compared with other types of technology and with this perception of the problem, the search for solutions entailed finding means for controlling this complexity. It was demonstrated, however, that academic and commercial research was still constrained within mechanistic principles and was, therefore, treating the surface appearances of the problem but not the deep contradictions it revealed.

By applying the synthetic model to this process, the difficulties being experienced were explained not in terms of the mechanistic model but as a consequence of it. Those difficulties, it was argued, revealed the contradictions arising in practice between mechanistic assumptions and the reality to which they were being applied. The changes resulting from attempts to overcome these contradictions were shown to maintain the integrity of the mechanistic precepts and not to address their fundamental nature. This interpretation of techological change as a consequence of the dual moments of contradiction and institutional momentum was reinforced through its application in more detail to one particular development method, prototyping. This example demonstrated the potential complexity of responses to contradiction and the importance of understanding technological change through an examination of its manifestations at different levels of detail. In this way the understanding acquired at each level informs the investigation of the others replicating the dual relationship through which technological change itself occurs.

The final aspect of computer technology examined in the empirical part of the thesis was artificial intelligence. This provided an opportunity to apply the lessons of the previous empirical investigation to another and potentially fruitful area. In so doing, it highlighted the implications of assimilation as a response to contradiction, and thus began to address some of the broader social issues which arise from the themes developed in this thesis. It also brings us to the point where we must consider the value of the conclusions it has reached by developing those themes. The justification for a number of the decisions made in the career of this thesis has been left to the evidence of their successful empirical application. These questions must now be resolved. I propose to do that in the remainder of this chapter by looking at three further questions arising directly from the empirical evidence offered; whether the synthetic concept of technology does indeed enhance our understanding of technology, whether the empirical evidence offered represents an adequate test of that concept, and whether it enhances our understanding of the broader social domain in which technology exists.

THE WIDER CONTEXT

Do Computers Represent a Special Case?

A key question in evaluating the conclusions of this thesis, is whether they have a wider relevance than their immediate empirical object; computer technology. The value of computer technology as an area for research has been to stretch the positivist concept of technology to the point where its limitations are clearly exposed. A similar situation was identified in physics where the complex relationships made apparent by studies of matter close to the speed of light could not be explained within the framework of Newton's laws. In Capra's words:-

> The mechanistic world view of classical physics was based on the notion of solid bodies moving in empty space. This notion is still valid in the region that has been called the 'zone of middle dimensions', that is, in the realm of our daily experience where classical physics continues to be a useful theory. Both concepts - that of empty space and that of solid material bodies - are deeply engrained in our habits of thought, so it is extremely difficult for us to imagine a physical reality where they do not apply. And yet, this is precisely what modern physics forces us to do when we go beyond the middle dimensions. (3)

In this case the result has not been a fundamental reassessment of earlier physics, but the creation of a special category, a new paradigm appropriate to atomic physics which does not intrude on the concepts of time and space used in Newton's mechanistic model of Nature. As a result of this accommodation, the lessons of atomic physics do not have significant consequences from the perspective of Newtonian physics and have largely been ignored.

My purpose here is not to debate that particular accommodation, but to identify it as a possible response to the contradictions in computer technology and to argue that as such it is inappropriate. The foundations of that case lie in the argument that positivism demonstrates a persistent tendency to impose its own rationality and formality in pursuit of predictabilty and control. The progress of the Industrial Revolution in nineteenth century Europe, it was suggested, could be understood in these terms. Machines were invented to increase control over natural resources, whilst the factory system and the division of labour increased the 'efficiency' of the labour process, and new financial and governmental institutions created a compatible social infrastructure. These various moments in the rationalisation of a society cannot be described in a linear and causal fashion, they fed off each other's contradictions in a complex working out of the mechanistic concept which had become established in the principles of social cohesion. It is the contention of this thesis that the development and use of computers is part of this same and continuing process of rationalisation and that computer technology should not be treated as a special case but as one which can throw a new light on the earlier consequences of the autonomous logic of which it is a part. The progress of this rationalisation was charted in the last chapter in terms of the increasing complexity signified by the terms data, information and knowledge processing. These stages are not separate from those represented by the Industrial

Revolution, but part of the same escalation of rationality which epitomises technological societies and which, in the development of expert systems and other artificial intelligence applications, is threatening to assimilate all forms of social interaction to the mechanistic model. This does not imply that computers are the necessary consequence of an inevitable development in mechanistic logic, less still of any fundamental progression. However, they are part of the same continuity, and as such they can be used to increase understanding of it and, within that context, to provide a fruitful illustration of its contradictions.

<u>How Positivist Technology Survives the Contradictions</u>

If computer technology has the potential for such a powerful critique of positivist technology, we must explain why the latter style continues to dominate industrial societies. This can be done, once again, by adopting the synthetic perspective. In this way, it is possible not only to identify the nature of technological change but to understand the power of positivism to survive, thus far, its own contradictions. The key to the explanation is that fundamental technological change only takes place when existing institutional resources are no longer able to respond to the contradictions occuring in action and within the institutional logic itself. At this time, a crisis is precipitated which brings about not simply a change of expression in the institutional logic but its replacement by an alternative form (4). Marx describes the crisis which brings about this change in terms of modes of production.

> At a certain stage of their development, the material productive forces of society come in conflict with the existing relations of production, or - what is but a legal expression for the same thing - with the property relations within which they have been at work hitherto. From forms of development of the productive forces these relations turn into their fetters ...... No social order ever perishes before all the productive forces for which there is room in it have developed; and new, higher relations of production never appear before the material conditions of their existence have matured in the womb of the old society itself. (5)

Habermas sees it rather as a failure of legitimation.

> A rationality deficit in public administration means that the state apparatus cannot, under given boundary conditions, adequately steer the economic system. A legitimation deficit means that it is not possible by administrative means to maintain or establish effective normative structures to the extent required. (6)

The consequences, however, are substantially the same. The principles on which the society is based are no longer able to maintain cohesion and give way to an alternative form. The simple explanation of why positivism still dominates the conception of technology, therefore, is that the contradictions described in this thesis have not yet exhausted its potential to respond to them or to retain its normative legitimacy. The explanation of why this should be has a number of elements.

Consider one of those elements, the institutional logic of technology, we must firstly remind ourselves of the close relationship between a society and the technology which sustains it. This relationship is not simply one of association, but of mutual dependence which does not consist of one causing change in the other but of each changing in sympathy with the other. Any fundamental challenge to technology, therefore, represents a contradiction to the principles on which the whole society is based and implies a similarly fundamental change in them. In the case of modern industrial societies, this link is especially strong because the principles of social cohesion are themselves derived from the mechanistic implementation of positivism. It is, perhaps, in recognising the strength of this bond that Marx may be mistaken for a technological determinist. But his argument is not that technological change causes social change. Rather, he is saying that they are both parts of the same process, but that technology, in the sense of being the means by which humans interact with their environent to meet their basic physical needs, is an important and identifiable element of that process which provides a suitable measure of change between historical epochs.

The principles in which social cohesion is grounded are not pertinent only to the meeting of physical needs they are also the basis of the emotional and psychological stability of a society's members. They underlie the everyday assumptions and the shared meanings which make social interaction possible. In a modern industrial society, therefore, a challenge to the fundamental viability of the mechanistic model of reality questions the normal mode of being for its members. If the basis of that model was entirely illusory, of course, its inability to survive the evidence of daily experience would quickly undermine it. However, one of the strengths of positivism is that it is grounded in what would seem to be a necessary feature of the human mode of making a way in the world. In Capra's words:-

> In ordinary life, we are not aware of [the] unity of all things, but divide the world into separate objects and events. This division is, of course, useful and necessary to cope with our everyday environment, but it is not a fundamental feature of reality. It is an abstraction devised by our discriminating and categorizing intellect. To believe that our abstract concepts of separate 'things' and 'events' are realities of nature is an illusion. (7)

The basic flaw of positivism is the assumption that this illusion is reality. The application of positivist principles formalises the creation of categories (scientific method) and ossifies the categories themselves (scientific knowledge) which are then claimed to have special validity. The strength of positivism is derived from its appeal to an essential element of the human mode of being-in-the-world, a sense of stability and predictability. What is lost as a consequence is the flexibility necessary to explore beyond those categories and understand the process by which they change.

This claim to undue legitimacy is not only of relevance to events occurring in the present. A belief in the traditional validity of technology is also a necessary justification for the machines and methods which have been the source of relative prosperity and power since the industrial revolutions in Europe. As Braverman argues, there is:-

> ...... "a product cycle" which invents new products and services, some of which become indispensible as the conditions of modern life change to destroy alternatives. (8)

Braverman's discussion is directed at the specific implementation of industrialism in capitalist societies, but its alternative implementations are no different in this respect. In each case, positivism offers the same justification for this dependence by claimimg that it is part of a progressive and natural development (9). Even though this claim is not justified, the powerful inertia and dependence resulting from the application of positivism has given its principles a mass which is very difficult to divert. It is not that the contradictions experienced in practice have had no effect. In the case of computer technology they have clearly resulted in significant changes, but they do not, as yet, constitute a strong enough challenge to the underlying principles of technological society to undermine the latter's dominance.

This dependence on positivsm, however, is not only a generalised phenomenon of industrial societies, but is continually reinforced by the pervasivness of its direct relevance to individuals, groups, organisations and institutions. At the individual level, for example, an unemployed person might perceive their own interests to lie in the construction of a new factory regardless of its effect on the ecological balance of the area it will occupy. For others positivism is a source of privilege. Experts and professionals rely on the status it gives to their knowlege so that, for example, the members and servants of government draw legitimation from their role as arbiters of the complex social and economic structure of modern societies. The benefits need not be personal to this extent. In market economies many companies base their profits on goods marketed by an appeal to 'scientific' qualities. A more subtle form of privilege is identified by Paczuska who suggests that male domination is predicated on the assumed superiority of the masculine characteristic of rationality, by which is meant positivist rationality. This she believes reaches into classrooms in the formal principles embodied in some computer languages. Hence she reports one researcher's assertion that:-

> ...... the culture of BASIC is itself male, even macho. "Computer languages don't have learning styles, but the culture that grows up round them does." (10)

Some social institutions, notably science and technology, derive their very raison d'etre from the positivist principle on which society is based. Thus, in asking why artificial intelligence researchers do not recognise the inherent contradictions in their assumptions, the Dreyfuses suggest:-

> The answer is that the spokesmen for the AI community have a great deal at stake in making it appear that their pure science of artificial intelligence and its engineering offspring, expert systems, are solid, established, and non-controversial. They will do whatever is required to preserve that image. (11)

Although brief, this discussion clearly indicates the substantial resources which positivism, as the epistemology of industrial societies, can marshall in its defence. We should not be suprised, therefore, that it is able to respond to the contradictions to which it gives rise without compromising its essential nature. It is firmly embedded in the traditions and the present of those societies and has become essential for the physical and psychological well-being of their members. The contradictions exposed by computer technology can only be one form of action among many if sufficient momentum is to be generated to substitute an alternative set of social principles. The final part of this chapter will assess how far this thesis has gone in establishing the viability of that action as a means of exposing the questions raised by the dominance of positivism and in identifying what further can be done to strengthen its case.

FURTHER DIRECTIONS FOR RESEARCH

What Has Been Done?

It has not been an objective of this thesis to deliver a polemic against the use of computers or the implications of artificial intelligence. No more is it a critique of the technology of modern industrial societies. It does not reject analytical thinking, indeed it recognises the pragmatic necessity of analysis in everyday praxis. Also the synthetic concept of technology has itself benefitted from analysis both in its construction and in its demonstration. What it does offer is an alternative means for understanding technology and the way it changes and hence the possibility of re-evaluating both its products and the principles on which they are based. This does not constitute a rejection of analysis, but an attempt to establish a new context for its use. Thus it is not simply a question of doubting the final certainty of knowledge as Popper does, it requires that we recognise both the limitations of analysis and, within those limitations, the contextual and pragmatic nature of the knowledge which it produces. In essence, therefore, this thesis seeks to demystify the nature of 'technological' knowledge. Winograd and Flores reflect a similar motive in the concluding words of their own book:-

> ...... we can work towards unconcealment, and we can let our awareness of the potentials for transformation guide our actions in creating and applying technology. In ontological designing, we are doing more than asking what can be built. We are engaging in a philosophical discourse about the self - about what we can do and what we can be. Tools are fundamental to action, and through our actions we generate the world. The transformation we are concerned with is not a technical one, but a continuing evolution of how we understand our surroundings and ourselves - of how we continue becoming the beings we are. (12)

This thesis, through its interpretation of technological change, offers its own contribution to that process of revealing. It recognises that positivist technology, through its rationalist logic, has created expectations for its own success which are now being brought into question by the experience of its application. This does not imply that this technology is wrong (within the terms of its own paradigm), or that there exists a conspiracy to conceal its inadequacy. Rather it indicates that there is a fundamental flaw in the positivist logic, a flaw which this thesis has shown to have two main elements. Firstly, positivist principles are unable to account for all types or degrees of complexity, and secondly, they do not have the potential to overcome this inadequacy from their own resources.

Other writers have recognised the limitations of the positivist concept of technology, but usually been unable to see a process by which they may be overcome (13). Winograd and Flores also appear to reflect this pessimism.

> Computers, like every technology, are a vehicle for the transformation of tradition. We cannot choose whether to effect a transformation: as designers and users of technology we are already engaged in that transformation, independent of our will. We cannot choose what the transformation will be: individuals cannot determine the course of a tradition. Our actions are the perturbations that trigger the changes, but the nature of those changes is not open to our prediction or control. We cannot even be fully aware of the transformation that is taking place: as carriers of a tradition we cannot be objective observers of it. Our continuing work toward revealing is at the same time a source of concealment. (14)

In formulating its case, this thesis seeks to provide not only an explanation of how 'tradition' reacts to 'perturbations' but also a realistic framework for action. Identifying the central role of positivist/mechanistic principles in maintaining the social cohesion of industrial societies does not lead to a denial of the role of human action in change. Nor does it assume that action against individual forms of technology is ineffectual. Instead, recognising that there will be greater moment in changes occuring at the institutional level, it offers a means of identifying the most effective forms of action. Similarly, it directs critique to where it will expose the internal contradictions within institutional technology in order to exploit them much as did Marx with capitalist economic principles. At the same time there is a realistic assessment of the potential and consequences of such actions in view of the resilience of positivism at both social and institutional levels. It also highlights, therefore, the need to persist in action and critique against the new, and perhaps unintended forms of technology that may emerge as a result of previous action. This is helped by the basis it provides for exposing and criticising responses to contradictions; identifying the existence of repression, the dangers of assimilation and the inadequacy of accommodation. It also recognises that sympathetic change in other institutions is necessary for the most effective accumulation of contradictions. Finally it shows the requirements for the development of an alternative position, what it must account for and what it must avoid to create a viable alternative. In all this, the synthetic perspective does not claim to provide the means to 'engineer' the future, that is clearly alien to its own logic, but equally, it does not require simple acquiescence in an inevitable future of domination.

None-the-less, when we see the massive resources of resistance available to positivism, we can appreciate that a challenge which can be relegated to the extremes of experience is unlikely to have a major impact. Hence the importance for the critique offered by this thesis to locate itself in the mainstream of technology and not allow itself to be relegated to the fringes. As the synthetic model itself makes clear, technology is a pragmatic institution. If the contradictions exposed by computer technology can be accommodated in a separate paradigm or assimilated into the existing one, it is unlikely that they will be taken into account in debates on other forms of technology. It is the argument of this thesis however, that to accept this response would be to accept significant dangers for society as a whole because the contradictions and logical momentum of mechanistic positivism exposed by computer technology are relevant to all forms of technology. It would also be a rejection of the opportunity presented by computer technology, as an empirical domain, for reviewing and analysing society in its broadest sense.

Although it is beyond the scope of this thesis to explore other forms of technology, it has indicated some of the areas in which the synthetic concept offers a new perspective on them. For example, the ideas of contradiction and response provide an alternative explanatory framework for the phenomenon of 'technological fix'. It need no longer be seen simply a consequence of the positivist reticulation of knowledge, rather it can be located in the complex within which positivism responds to contradiction without compromising its essential principles. Of course, the synthetic concept of technology does not provide the only alternative perspective, Eastern philosophy, for example, was applied to this task throughout the 1960s and, as Capra suggests, may have much more to contribute yet. What the synthetic concept does offer however is an appraisal of the relationships within institutional technology in a form more easily identifiable in terms of their positivist origins. It goes some way, therefore, towards realising the possibilities offered by Foucault's work whilst evading some of the obscurities and pessimism which his theoretical position forced him to adapt.

Poster (15) highlights this potential in Foucault's work and characterises its advantages by contrasting a Marxist analysis based on the mode of production with one based on what Poster calls the 'mode of information'.

> The term 'mode of information' designates the new language experiences of the twentieth century brought about for the most part by advances in electronics and related technologies ...... I employ the term mode of information to designate forms of linguistic experience that have emerged in the course of the twentieth century ...... The language form unique to the mode of information that receives most attention today is that of individual to computer. (16)

For Poster, computers signify much of what is different about the mode of information.

> The line dividing subject and object is blurred, far more than it was in Marx's analysis of labour. Which is the subject, computer or individual? Which has the capacity to generate knowledge, has greater mental powers? (17)

Foucault's work, says Poster, highlights the changes in historical forms of domination which in feudal times were directed at the body, in early forms of capitalism at productive activity but which in modern industrial societies are concerned with language and communication.

> Foucault's category discourse/practice draws the attention of critical theory to systems of language as they are related to and shape experience. (18)

Poster's argument is that the society which Marx analysed no longer exists and a new perspective is required to take account of the changes. The concept of mode of information provides this by supplementing Marx's analysis based on the mode of production. This is not unlike the case made by Habermas, but whereas he, and Foucault, lose the basic insights of Marx, Poster sees the two as complimentary, although the category discourse/practice offers the better framework for an analysis of domination through language. In tentatively exploring the new dimension represented in the interface between people and computers, this thesis may be considered as one contribution to such an analysis.

What Is Still To Do?

However successful this thesis may be judged to have been in achieving its objectives, its horizons are limited. At best, it can only make an initial inroad into the work required to establish the viability of its claims. Those claims may be categorised into four types, theoretical, empirical, methodological and practical. These final paragraphs will explore briefly the work still to be done to substantiate those claims. The claim to practical value is perhaps the most difficult to sustain or develop at this stage. Certainly it is unlikely to receive much support solely on the basis of the arguments presented above. For the present, therefore, this must remain a possibility whose realisation will be dependent on the directions in which the arguments can be developed by further theoretical and empirical advances.

The more immediate possibilities for development are a direct consequence of the methodology adopted in this thesis, in particular its claims for the validity and value of expert participation as a means of identifying, analysing and substantiating ideas about technology. This method, it has been argued has provided a special and valuable insight into the nature of computer technology. In doing so, it has adopted a pragmatic approach to both theory and empirical evidence.

Consequently, the principal objective of its theoretical considerations has been to create a working hypothesis with which to investigate computer technology and the empirical discussion has aimed at providing a first test of the viability of that hypothesis. However, this methodology can only do so much and the limitations of expert participation as a method of research give rise to the opportunities for the further work which will establish its case more firmly.

Because the synthetic concept of technology was described as a working hypothesis, the emphasis in its use has been on its pragmatic value for understanding an empirical subject. Its success in this venture does not necessarily endow absolute validity on that hypothesis, but then such an accolade would be contrary to the principles on which this thesis has been developed. However it does open posiibilities for further theoretical development and the clearest direction this can take is to turn the brief excursions into the work of other theorists into a sustained analysis. This will mean returning to the original authors, and their commentators, in order to examine their positions more rigorously, to identify how the synthetic concept of technology addresses the various issues they raise and to demonstrate how its own case can be validated by comparison with theirs. A similar exercise could also be undertaken with theoretical work not considered in the original development of the synthetic concept.

Valuable as this will be, the potential for expanding the empirical case is perhaps even greater. It has been argued in this chapter that although computer technology is operating at the limits of mechanistic principles, it is not a special case. However, evidence from that domain alone cannot establish the value of the synthetic concept or the validity of its claim to general relevance. Instead it must be applied to a broader base, in particular to other, more traditional types of technological practice (19). Only in this way will it be made clear that the arguments presented in this thesis are relevant to all forms of technology. With the additional support of greater theoretical rigour, the synthetic concept of technology will then be equipped to offer a broad critique and a basis for action in the technological domain.

NOTES FOR CHAPTER 8

1. Although it never became an issue for this thesis, it is likely that a similar dificulty would have been experienced with the concept of knowledge; see for example Hamilton P. 'Knowledge and Social Structure', 1974, Routledge and Kegan Paul, London. Certainly it seems to apply to other concepts; see for example Larrain J. 'The Concept of Ideology', 1979, Hutchinson, London.

   In resolving its own problems with technology, the thesis also explains the disorientation which Winner identified as characterising commonsense uses of the term (see chapter 1).

2. The first decision process was, of course, the identification of a 'problem'.

3. Capra F. 'The Tao of Physics', 1983, Flamingo, London, p. 74

4. The extent and forms of the violence which accompanies such a change depend on a number of contextual influences, for example the extent to which the new social principles have already been established in the society.

5. Marx K. 'Preface to A Contribution to the Critique of Political Economy', in 'Karl Marx and Frederich Engels - Selected Works', 1968, Lawrence & Wishart, London, pp. 181-2

6. Habermas J. 'Legitimation Crisis', 1976, Heinemann, London, p. 47

7. Capra F. 1983 op cit. p. 142

8. Braverman H. 'Labour and Monopoly Capitalism', 1974, Monthly Review Press, London

9. Recognition of this dependence is not new, see for example Berg M. 'The Machinery Question and the Making of Political Economy 1815-1848', 1980, Cambridge University Press, Cambridge

10. Paczuska A. 'Getting the Girls to Come Out to Play with the Boys' in *Computing* 4/9/86, p. 30

11. Dreyfus H.L. & Dreyfus S. 'Mind Over Machine', 1986, The Free Press, New York, p. 13

12. Winograd T. & Flores F. 'Understanding Computers and Cognition', Ablex Publishing Corp., Norwood N.J., p. 179

13. This pessimism was found to be a feature of other non-positivists, see chapter 2.

14. Winograd T. & Flores F. 1986 op cit. p. 179

15. Poster M. 'Foucault, Marxism and History', 1984, Polity Press, Cambridge

16. Ibid. pages x., 164 and 166

17. Ibid. p. 167

18. Ibid. p. 163

19. This does not mean, of course, that the potential of computer technology as an empirical subject has been exhausted. For example, recently released material about British computers in World War II might reveal a great deal about the adoption of the von Neumann architecture and the origins of artificial intelligence.

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